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USES OF THE SEPARATED STABLE ISOTOPES OF OXYGEN

HUGH S. TAYLOR

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(*Read April 25, 1947*)

THE physical and natural sciences have at their disposal as a result of the developments of the last twenty years two groups of isotopic elements which may be employed as tracers or messengers in further scientific explorations. The first of these are the naturally occurring, non-radioactive stable isotopes, of which heavy hydrogen or deuterium is the best known and utilized. The second group includes the naturally occurring radioactive isotopes which have been known since the early days of radioactivity, the isotopes produced by processes of nuclear change with high speed neutrons, protons, deuterons, and alpha-particles as bombarding agents for the transformation of stable nuclei, and, more recently, the rich sources of radioactive elements yielded by the neutrons which accompany the fission of uranium in chain-reacting piles. Both the stable and the radioactive tracer elements have their special functions and applicability, dictated in part by their availability and in part by the limitations imposed by the problem in which they are to be utilized as tracer elements.

The significance of the word "stable" in the title of the subject under consideration arises immediately from an examination of the properties of the presently known radioactive isotopes of oxygen which have masses 15 and 19. The pertinent data are shown in the following table.

RADIOACTIVE OXYGEN ISOTOPES

Mass	Half Life	Radiation
15	2.1 minutes	β^+
19	31 seconds	β^-

The positron emission from ^{15}O and the brief half lives of both species make their experimental use a matter of great technical difficulty. It is not surprising therefore that there exists no literature on the radioactive oxygen isotopes in tracer work and that all the work in this area is confined to the stable isotopes. These are three in number and their masses and abundances are evident from the following summary.

STABLE OXYGEN ISOTOPES

Mass	Abundance
16	99.76
17	0.04
18	0.20

The great predominance of oxygen of mass 16 together with the difficulty of separation has militated against research work with the stable isotopes of oxygen. Hitherto, the main bulk of heavy oxygen compounds used in isotope studies has been obtained by the distillation of water, which, as was shown by G. N. Lewis and Cornish, in the early days of heavy hydrogen research in 1933, produces small changes in density. Further, to these changes the disturbance of the oxygen isotope ratio as well as the hydrogen isotope ratio was a contributing factor. Even, however, with distillation columns having many equivalent theoretical plates, that is, a large fractionating efficiency, the resulting water available for experimental work in the field represented, in the main, displacements in density of a few hundred parts per million. This meant, in its turn, difficult techniques of density determination in the tracer experiments. It seems evident that, in contrast with heavy hydrogen and heavy nitrogen where much greater concentrations of the heavy species became available, research with heavy oxygen tracer compounds has been thereby at a marked disadvantage.

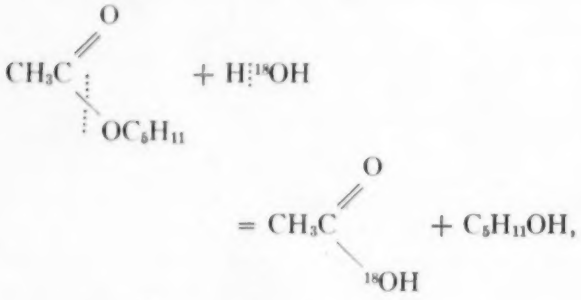
THE TRACER TECHNIQUE

The typical problem in the use of oxygen isotopes as tracer elements may be generalized thus. Oxygen exists in combination with other elements attached by single bonds to two other atoms or groups of atoms, R_1 and R_2, in the generalized compound R_1OR_2, or attached by a double bond as in such compounds, for example, as RC=O. With singly bonded oxygen compounds a typical tracer reaction may be generalized by the equation

$$R_1OR_2 + HOH = R_1OH + R_2OH.$$

If the oxygen contained in the water molecule, HOH, is "labelled" by being enriched in heavy

oxygen, it can be ascertained whether the molecule R_1OR_2 breaks by reaction with water to R_1 and OR_2 or whether it breaks to form R_1O and R_2 since the heavy oxygen from the water will be located finally either attached to R_1 in the first case or R_2 in the second case. Polanyi made an early test in this manner to decide an old problem in organic chemistry which had been the object of much discussion, with no decisive answer prior to the use of heavy oxygen. In the reaction of esters, for example amyl acetate, with water according to the equation,



by using water enriched in oxygen 18, it was possible to show that none of the heavy oxygen went into the amyl alcohol, $C_5H_{11}OH$, which was produced, that, on the contrary, it was to be found in the acetic acid, $CH_3CO^{18}OH$. Evidently, in the process of hydrolysis or reaction with water, the oxygen bond between O and C_5H_{11} breaks less easily than the bond between $CH_3C{=}O$ and $-OC_5H_{11}$. The vertical dotted lines indicate where the two compounds break during the reaction to form the products.

The formation of ethers, which involves the reverse process of withdrawal of water from two molecules, such as alcohols which contain hydroxyl (OH) groups, can also be examined by the tracer technique. In this case sulphuric acid is used to facilitate the removal of water.

$$\underset{\text{Ethyl Alcohol}}{2C_2H_5OH} \xrightarrow[\text{Sulphuric Acid}]{H_2SO_4} \underset{\text{Ether}}{C_2H_5OC_2H_5} + \underset{\text{Water}}{HOH}$$

The process may be regarded as occurring in two stages, a compound formation between alcohol and sulphuric acid, giving ethyl sulphuric acid, $C_2H_5OSO_2H$, and water. How the ethyl sulphuric acid reacts with a second molecule of alcohol can easily be ascertained if the alcohol molecule is "labelled" with heavy oxygen as the following chart shows:

$$C_2H_5{}^{18}OH + C_2H_5OSO_2OH \rightarrow C_2H_5{}^{18}OC_2H_5 + HOSO_2OH.$$

It is the oxygen of the second alcohol molecule which enters the ether or, otherwise expressed, the molecule of alcohol enters into the final reaction as the fragments $C_2H_5{}^{18}O$ and H and not as the fragments C_2H_5 and ^{18}OH. Again the tracer technique locates with precision the place where the molecule breaks.

TRACER TECHNIQUE IN PHOTOSYNTHESIS

It has long been known that the photosynthetic process by which carbohydrates are built up in plant life with the assistance of chlorophyll and sunlight involved both carbon dioxide and water as the raw materials for the synthesis. It was known also that, in the synthesis process, oxygen gas is eliminated. Popularly stated, plants consume carbon dioxide and exhale oxygen. Such a statement could well give rise to the belief that the oxygen comes from the carbon dioxide. That such is *not* the case emerges from a research by Ruben, Randall, Kamen, and Hyde in the University of California. They showed that the green algae, *Chlorella*, produce oxygen from the water, not from the carbon dioxide. If the water was "labelled" with oxygen 18 and ordinary carbon dioxide was used the resulting oxygen was heavy oxygen. If the carbon dioxide was "labelled" with the heavy isotope and the water was normal then the resulting oxygen was also normal. That is, the oxygen evolution in green plant photosynthesis is due to the water molecule, H_2O, acting as a donor of hydrogen for a reduction of carbon dioxide.

Certain bacteria also possess photosynthetic activity. The process occurring is in some cases parallel to that occurring in plants; in some cases however there is divergence. In one such case, carbohydrates are built up by a chlorophyllous pigmented bacterium, but no oxygen is liberated. The activity is dependent upon the presence of other hydrogen providers than water. Hydrogen sulphide, H_2S, can so act, sulphur remaining as the hydrogen is consumed. Thus

$$\underset{\text{Carbon dioxide}}{CO_2} + \underset{\text{Hydrogen sulphide}}{2H_2S} = \underset{\text{Carbohydrate}}{(CH_2O)} + \underset{\text{Water}}{H_2O} + \underset{\text{Sulphur}}{S}$$

As a result of such studies, in which the use of heavy oxygen is an important factor, the present concept of photosynthesis involves an oxidation-

reduction process, induced by light, in which the carbon dioxide acts as an acceptor of hydrogen supplied by a suitable donor in presence of particular pigments of which chlorophyll is the commonest. Fruitful developments and extensions of this point of view are in progress.

OXYGEN ISOTOPES AND SURFACE CHEMISTRY

The use of isotopes in reactions at surfaces, notably the catalytic reactions, began as soon as heavy hydrogen, deuterium, became available in quantity. Important results were obtained in the study of catalytic mechanism in a variety of reactions in which hydrogen was an important constituent. The fundamental studies of such industrially important processes as the synthesis of ammonia from nitrogen and hydrogen, the reactions of hydrocarbons such as the cracking processes, polymerization to produce aviation gasoline, the production of toluene from petroleum for explosives in World War II were all assisted by the use of heavy hydrogen as a tracer in reactions at a variety of catalyst surfaces. The relative ease with which deuterium could be obtained for such studies made a large program of work possible.

Thus far, the availability of heavy oxygen is small and the volume of research undertaken correspondingly restricted. Nevertheless, many of the important technical catalytic processes and surface reactions are oxidation processes involving oxygen, and a like measure of successful research as was attained with deuterium can be expected as the heavy oxygen isotope becomes more available. Combustion processes, the oxidation of metals, the use of steam as an oxidation agent, catalytic reactions involving oxygen-containing compounds all await ready availability of oxygen isotopes. The possibilities in this direction will be illustrated by a single example drawn from the recent literature.

One of the important methods of separating gaseous isotopes is the method of thermal diffusion devised by Clusius. It has been known that, in a closed system containing a mixture of two gases maintained under a temperature gradient, the lighter gas of the mixture concentrates at the hot end and the heavier gas at the cold end. Clusius multiplied this separative effect by enclosing a gas mixture in a long vertical cylindrical column, in the axis of which was a hot wire, the walls of the column being kept cool. In this way the light gas travels upwards along the hot wire and the heavier gas descends along the cold walls. Eventually the gas at the top of the column is rich in the lighter species; that at the bottom is concentrated in the heavier species. Since oxygen molecules (O_2) contain two atoms and since the oxygen-18 atom has only a normal abundance of 0.2 per cent, the majority of oxygen molecules have a mass of 32, $^{16}O_2$, some have a mass of 34, $^{16}O^{18}O$, and only a negligible few have a mass of 36, $^{18}O^{18}O$.[1] In a Clusius column one would anticipate that oxygen would be separated into fractions rich in mass 32 at the top of the column, rich in mass 34 at the bottom of the column. When Clusius performed this separation in a tall column in which the heating element was a platinum wire, the experiment revealed that mass 32 did arrive at the top but that, at the bottom of the column, the oxygen was rich in mass 36, not mass 34. It was immediately evident that, on the hot platinum wire, an exchange reaction had taken place catalytically, two molecules of mass 34 yielding one of mass 32 and one of mass 36 according to the equation

$$\underset{2(34)}{2^{16}O^{18}O} = \underset{(32)}{^{16}O^{16}O} + \underset{(36)}{^{18}O^{18}O}$$

The separative action of the column forced the reaction over to the right hand side of the above equation. That this was due to the platinum acting as a catalyst was proved by a parallel experiment with nitrogen molecules (N_2) which are mainly mass 28, $^{14}N^{14}N$, and mass 29, $^{14}N^{15}N$. Platinum is *inactive* for the nitrogen exchange and so the gas at the bottom of the column had a mass of 29, not, as it would have been if the platinum had acted catalytically, a mass of 30, $^{15}N^{15}N$.

INORGANIC OXYGEN EXCHANGE REACTIONS

Urey and Greiff in an early important paper pointed out that many oxygen-containing inorganic substances would exchange with other oxygen-containing substances, notably water, to yield equilibria which might be utilized to enrich the desired oxygen isotope in one or other of the reacting species. Thus, carbon dioxide and liquid water equilibrate according to the reaction

$$C^{16}O_2 + 2H_2{}^{18}O = C^{18}O_2 + 2H_2{}^{16}O$$

in such a way that ^{18}O is concentrated in the carbon dioxide. The enrichment factor of 1.047 at 0° C. indicates that ^{18}O can be accumulated in

[1] The ^{17}O isotope is ignored in this discussion for simplicity and because its concentration is so much lower than that of ^{18}O.

carbon dioxide if this single separation factor can be multiplied. Urey and his colleagues found this multiplicative process in a continuous countercurrent flow of liquid and gas, using the technique of the fractionating column. For a column equivalent to n single exchange units an overall factor of α^n is obtained where α is the single separation factor. This chemical exchange method has been successful with nitrogen and the carbon stable isotopes. It is obvious that it can be practicable also for production of heavy oxygen.

A large number of inorganic ions such as phosphate, sulfate, chlorate, chromate, phosphite, sulfite have been studied, since, in some cases, notably phosphate, the study is an essential preliminary to studies in biological systems where these ions are involved in the complex of metabolic processes. The reactions are sensitive to time, temperature, and especially to the acidity of the solutions. The use of oxygen isotope as tracer is therefore only to be used in such studies with caution and careful control of the determining factors.

ORGANIC OXYGEN EXCHANGE REACTIONS

Parallel studies of the manner in which oxygen exchanges with a variety of organic substances have also been achieved. Alcohols, glycerine, sugars, organic acids such as acetates and benzoates, nitro-compounds, amines, carbohydrates, and proteins have all been subjected to what must, as yet, be designated as preliminary studies. The writer is convinced that the quality of the work hitherto performed and its lack of decisive character are in large part due to the fact that investigators thus far have had to use samples enriched in ^{18}O to only a trivial amount in excess of normal isotopic ratios. As a consequence, the techniques of study have been laborious and slow, in contrast with work with deuterium, nitrogen, and now uranium, where separation has been substantially complete. A large-scale attack on the problem of separation of stable oxygen isotopes is due. The availability of supplies of materially enriched or even separated isotopes of oxygen would, in the writer's judgment, enormously accelerate the pace of development of tracer work especially in biological and medical studies involving such fundamental processes as respiration, nutrition, metabolism, enzymatic processes generally. There is at present a pent-up demand for large supplies of enriched oxygen preparations. Thus far, there are indications only that a limited supply of a several-fold concentration of ^{18}O in water is under the control of the Atomic Energy Commission for use by properly qualified applicants. The writer is assured by various interested scientists that if supplies were multiplied many hundred fold, and concentrations considerably increased, a large program of effort in nutritional, biochemical, and biological research could go forward with rapidity.

THE SEPARATION PROBLEM

For the production of quantities of enriched heavy oxygen or heavy-oxygen-containing molecules which such a program would entail three possible separation methods should be considered and their relative merits evaluated. It is reasonably certain that the distillation of water, by which most of the heavy oxygen thus far available has been secured, is not calculated to be successful for the larger scale production that is here envisaged. The capacity of a thermal diffusion process for separating oxygen can be closely calculated from the laboratory experiments of Clusius mentioned in a preceding section. It does not appear to lend itself readily to economical large-scale production. These considerations suggest that a choice would probably narrow itself down to the chemical exchange reactions on the one hand or the gaseous diffusion process on the other.

In both of these processes there exists a body of data which would be of value in designing the production units. Technical experience obtained with the separation of heavy nitrogen by countercurrent chemical exchange between ammonia and ammonium salt solutions could be translated into corresponding data for the design of equipment to produce exchange between oxygen-containing reactants. In the case of separation by gaseous diffusion the technical experience which resulted in the successful separation of the isotopic species ^{235}U and ^{238}U using uranium hexafluoride vapor is more than sufficient for the less complex problem of designing a unit for the separation of oxygen-containing gases. The Atomic Energy Commission has embarked on a large-scale research program involving the production of multimillion dollar machines which produce radioactive isotopes. A fraction of this expenditure on machines adapted to the separation of desired stable isotopes would yield rich dividends to research workers in this field.

ACKNOWLEDGMENT

This essay on the stable isotopes of oxygen was prepared with the assistance of a bibliography

kindly compiled by Dr. George D. Halsey. To him my best thanks are due. Attached herewith are the names of the principal authors and their publications in the field of isotopic oxygen.

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THE SCIENTIFIC ENVIRONMENT OF PHILADELPHIA, 1775–1790

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I

ONE day in the fall of 1775 John Adams with some fellow-members of the Continental Congress made an excursion on the Delaware to inspect Pennsylvania's new row galleys. On the *Bulldog* Adams met three Philadelphians, of whom, with perhaps a suggestion of amazement and something of grudging admiration, he wrote in his diary that night:

> Hillegas is one of our continental treasurers; is a great musician; talks perpetually of the forte and piano, of Handel, &c. and songs and tunes. He plays upon the fiddle. Rittenhouse is a mechanic; a mathematician, a philosopher, and an astronomer. Biddle is said to be a great mathematician. Both are members of the American Philosophical Society.[1]

Adams' experience was certainly not unique. No host could have invited half a dozen literate Philadelphians to his table any time after the final organization of the Philosophical Society in 1769 and not found at least one who had more than a passing acquaintance with one of the sciences. Men—and women too—watched the flowers and birds, thronged to scientific lectures, read and talked with learning and wit about air balloons, animal magnetism, and Mr. Peale's "Perspective Views with Changeable Effects," as he first called his "moving pictures."[2] Science in Philadelphia was the hobby of many individuals of every rank and persuasion. Some few sent communications to the American Philosophical and English county societies, while local clubs and the newspapers and magazines gladly received and heard the observations and arguings of neighborhood Newtons. After dinner one evening at Dr. John Morgan's, for example, Adams was shown by his host "some bones of an animal of enormous size found upon the banks of the river Ohio."[3] The report of a worm growing out of the eyeball of a horse in an Arch Street stable excited the city's men of science in 1782, evoking the liveliest speculations on spontaneous generation.[4] Some persons made daily meteorological observations.[5] Many more paid a guinea to attend three times a week Captain John Macpherson's popular lectures "on Astronomy, and every other branch of natural Philosophy."[6]

Indeed, this general, even passionate, devotion by amateurs to science and learning is one of the striking features of the city's cultural life after 1775. Dr. Franklin was still alive. For more than a generation his example had set a pattern—tradesman by day and philosopher by night—and the institutions he and his associates fashioned—the Library, the Philosophical Society, the College, the courses of public lectures at the Hospital and elsewhere—provided opportunities for the curious and the studious. The Reverend Nicholas Collin, pastor of Gloria Dei Church in the Quaker City, a collector of seeds, flowers, shrubs, and trees which he sent to his native Sweden, expressed a widely-held sentiment when he criticized two of his co-laborers in God as "only theologians, Greeks and Hebrews, of whom we cannot expect much for the advancement of science."[7] This was an age of brilliant amateurs, when an English dissenting clergyman discovered oxygen, a German music-master, self-taught in astronomy, found another planet, and a Philadelphia printer laid the foundation of the new science of electricity. All this was, of course, in the spirit of the eighteenth century Enlightenment. From St. Petersburg to Manchester, from Palermo to Edinburgh, Europe was a bubbling cauldron of ideas. No man of any respectability at all failed to toss his contribution into the pot. Literary and scientific societies were formed; papers were written, read, and printed; transactions were issued; grand plans for

[1] Diary, Sept. 28, 1775, *Works* II: 429, Charles Francis Adams, ed., 10 v., Boston, Little, Brown, 1850–1856.

[2] Arthur Lee to [—], Phila., Aug. 25, 1784, *Penna. Mag. Hist. and Biog.* **43**: 268, 1919; *Freeman's Journal*, Jan. 11, 1786. The *Pennsylvania Magazine* is cited hereafter as *PMHB*.

[3] Diary, Oct. 14, 1774, *loc. cit.* II: 397.

[4] M.D., To the virtuosi and lovers of natural history, *Penna. Gazette*, June 12, 1782; Hopkinson, Francis, Some further account of the before-mentioned horse, *Amer. Museum* **3**: 503, 1788.

[5] Brissot de Warville, J. P., *New travels in the United States*, 249–257, Dublin, printed by W. Corbet, 1792.

[6] *Freeman's Journal*, Jan. 2, 1782.

[7] Johnson, Amandus, trans., *The journal and biography of Nicholas Collin, 1746–1831*, 159, Phila., N. J. Soc. of Penna., 1936.

an empire of science, reason, and enlightenment were projected—on the Delaware as over the seas.

II

Of all the institutions of the city none better brought the scientific interests of Philadelphia to a focus than the American Philosophical Society. Heart and brain of the city's scientific life, it gave a tone to the whole community. Its American and international reputation was secured by the reputation of its president, Dr. Franklin, and by the observations of the Transit of Venus made under its auspices in 1769 and published in its *Transactions* two years later. The ablest men in the city were among its members and guided its work; and though it was a national body, drawing its membership from all the states and from Europe as well, the local members contributed most to it and probably derived the greatest benefit from it. Formed on the broadest basis, "in honest imitation of the Royal Society" of London,[8] the Philosophical Society by its simple being encouraged investigation into science and the applications of science and drew to itself the reports and observations of the scientifically-minded. No corner of pure or applied science was strange to it and the interests of its members ranged widely from agriculture to astronomy. Thus at a typical meeting—that of January 28, 1786—communications were received from Dr. John Ewing, provost of the University at Philadelphia, on a method of calculating the size of the earth; from Dr. Franklin on a hygrometer and the description of an urn stove; from Francis Hopkinson, Philadelphia lawyer, on further improvements to the harpsichord; from Captain Thomas Hutchins, geographer of the United States, on a waterfall in Fayette County, Pennsylvania; from Humphry Marshall, of Chester County nearby, on forest trees; and from Mr. Morrison, of Montreal, on the late dark day.[9]

Of somewhat less importance in Philadelphia's scientific firmament were the College of Philadelphia and its Medical Department. Science had, it is true, enjoyed a respected place in the intentions of the founders of the College; but the traditionalists quickly dominated the institution. Yet the original ideas of Franklin and some of his co-founders were never completely forgotten. Provost William Smith displayed a lively interest in science: he lectured on natural philosophy to the undergraduates and he was an associate of Rittenhouse in many astronomical observations.[10] It was in the Medical Department, however, that the sciences, especially botany and chemistry, received the most attention. All the medical professors were educated in science abroad. Morgan, who founded the medical school in 1765, was a Fellow of the Royal Society; Rush had studied chemistry with Cullen at Edinburgh and prepared for the use of his students in Philadelphia a syllabus of a course in chemistry; while Benjamin Smith Barton, more interested in botany than in medicine, author of a small work on natural history and American antiquities while yet an undergraduate, inspired a whole series of theses on medical botany by candiates for the degree of doctor of medicine at the University of Pennsylvania after 1790. Benjamin Rush might complain that the physicians of America "(who are the most general repositories of science)" were "chained down by the drudgery of their professions";[11] yet American science was the richer for their labors.

Other institutions of the metropolis both reflected and nourished the scientific interests of the Philadelphians. At the Library Company, as well as in the circulating libraries and in the collections of private gentlemen, were to be found the *Transactions* of the Royal Society and the English county societies, the writings of Bacon, the works of Boyle, the texts of the ablest medical men, and hundreds of books and pamphlets on the earth, air, stars, and rattlesnakes. Among the scientific works, once the property of Isaac Zane, Jr., of Frederick, Virginia, sold at auction in Philadelphia in 1783, were Catesby's *Natural History of Carolina,* Descartes' *Philosophy,* Euclid's *Elements,* Bacon's *Advancement of Learning,* Bradley's *Philosophical Works of Nature,* Lucretius' *De rerum natura,* Webster's *History of Metals,* Boyle's *Experimental History of Cold,* and

[8] Rosengarten, J. G., The American Philosophical Society, in Frederick P. Henry, ed., *Founders' week memorial volume,* 116, Phila., published by the City, 1909.

[9] Phillips, Henry, Jr., comp., Early proceedings of the American Philosophical Society, 1744–1838, *Proc. Amer. Philos. Soc.* **22** (3): 141, 1884.

[10] Hornberger, Theodore, *Scientific thought in the American colleges, 1638–1800,* 29, 55–56, 65–66, Austin, Univ. of Texas Press, 1945; Cheyney, Edward P., *History of the University of Pennsylvania, 1740–1940,* 134–135, Phila., Univ. of Penna. Press, 1940.

[11] To Lettsom, Phila., Oct. 26, 1786, Pettigrew, Thomas J., *Memoirs of the life and writings of the late John Coakley Lettsom* II: 428, 2 v., London, printed by Nichols, son, and Bentley, 1817.

Pliny's *Natural History*.[12] The advertisements of the booksellers reveal how common were works of more recent authorship.[13]

Through the magazines and newspapers, through public lectures, and through such institutions as Peale's Museum, science and the patter of science were brought to a still wider audience. Letters and articles and extracts from treatises on scientific subjects appeared regularly in all the periodicals. Some of these writings, to be sure, were rather on the level of Mr. Powell's account of his two-headed turtle, which, unfortunately, he never dissected, because it was seized by his cat and carried off and never seen again.[14] But even a two-headed turtle—especially a two-headed turtle, one thinks—might induce reflections on the mutability of species.

No season passed after the war without its course of lectures on scientific or pseudo-scientific matters. They ranged the gamut of science from archaeology and paleontology to anatomy and the science of man. In the spring of 1782 Dr. Gustavus Frederic Keilman, a pupil of Linnaeus from Upsala, was delivering at the Pennsylvania Hospital lectures on botany for medical students and laymen which were unique in that they included field trips in search of botanical specimens.[15] Electricity was always a popular subject; better than many lectures on it were those delivered in 1785 by Robert Patterson of the University, who illustrated them with a number of new and interesting experiments never before exhibited, he said, in any public lecture in Philadelphia.[16] A popular and ambitious series was inaugurated on January 11, 1786, when Dr. Henry Moyes, the blind scientist from New York, opened a course of lectures comprehending nothing less than "the Natural History of the Celestial Bodies, of the Earth, of the Atmosphere, of the Animal and Vegetable Kingdoms, with the History of Man, and the most effectual Means of preserving Health." Tickets were sold for one guinea the course, excepting that to ladies the price was but half a guinea.[17] As might be expected of such a course as this, truth and nonsense alternated. Dr. Moyes on February 22 lectured on the properties of common air, which he illustrated by experiments with air pumps and similar apparatus.[18] But Dr. Moyes also told his hearers that earthquakes are caused by electricity and that cities might be protected against catastrophe from that source by sinking steel conductors into the earth 'round about each city.[19]

The museums afforded still another opportunity for the instruction and entertainment of the citizens of Philadelphia. In several museums of sorts collections of natural and artificial objects might have been viewed before the war: the Library Company kept in Carpenters' Hall a jumble of instruments and curios—an air pump, a collection of fossils, a piece of marble from Herculaneum, the hand and arm of an Egyptian mummy;[20] while a collection of Indian remains was housed at Fort St. Davids.[21] It remained, however, for Pierre Eugène Du Simitière, a Genevan scholar and painter, who had spent ten years in the West Indies painting, collecting, and gathering data for a history of the European settlements in those islands, and had come to Philadelphia in 1766, to give the Quaker capital its first systematic museum.[22] With a clear aim, conscious of the significance of the times he lived in, Du Simitière tirelessly sought materials for the natural and political history of America. He dunned his friends for books, pictures, articles of primitive manufacture, and curiosities of all kinds. Thus his library and museum grew and their fame expanded until people came to see the collections in such numbers and with so little regard for the convenience of their owner that in 1782 he had finally to fix regular hours, at which times only he would conduct

[12] "Catalogue of Books the Property of Isaac Zane Junr. of Frederick Virginia . . . ," Coates-Reynell Papers, Zane Papers, Historical Society of Pennsylvania. The Historical Society is abbreviated hereafter as HSP.

[13] See, for example, Robert Bell's *Catalogue of a large collection of new and old books, in arts, sciences, and entertainment, for persons of all denominations* . . . , Phila., printed by Robert Bell, 1783.

[14] Powell, William H., Letter respecting a remarkable lusus naturae, addressed to a member of the Alexandria society for the promotion of useful knowledge, Jan. 24, 1790, *Amer. Museum* **8**: 85, 1790.

[15] *Penna. Gazette*, May 2, 1782.

[16] *Ibid.*, Jan. 12, 1785.

[17] *Penna. Packet*, Jan. 3, 1786.

[18] *Ibid.*, Feb. 17, 1786.

[19] *Ibid.*, Feb. 13, 1786.

[20] Library Company of Philadelphia, *The charter, laws, and catalogue of books. . . . With a short account of the library prefixed*, 4–5, Phila., printed by Joseph Crukshank, 1770.

[21] John Godman to William Milnor, March 2, 1830, *PMHB* **21**: 417–418, 1897.

[22] Potts, William J., Du Simitière, artist, antiquary, and naturalist, projector of the first American museum, with some extracts from his notebook, *PMHB* **13**: 341–375, 1889; Huth, Hans, Pierre Eugène Du Simitière and the beginnings of the American historical museum, *ibid.* **69**, 315–325, 1945.

parties through.[23] Du Simitière was, as his biographer has said, "the first and ablest *general* collector of judicious materials for North American history, collected and arranged in a systematic and methodical manner." [24] Du Simitière's ambition and object were in fact nothing less than to make his private collection "the foundation of the first American Museum." [25]

This praiseworthy object he never lived to realize. Du Simitière died in 1784 and his collections were sold. Many of the books, papers, and sketches were bought by the Library Company; much of the natural history went to Charles Willson Peale. Two years later Peale opened a museum which eventually surpassed Du Simitière's and which itself became, in a sense, the first, i.e., ranking, American museum. At once a business enterprise and an educational institution, Peale's Museum was the best kind of popularized science. It was distinguished by the skill with which the exhibits were presented and the means devised to make them instructive. Everything was arranged in orderly and systematic fashion; birds and animals were posed in life-like postures, and backgrounds were painted in to suggest the natural environment. One exhibit, much commented on, was of the fangs and poison ducts of a rattlesnake, which were placed beneath a lens that they might be the more closely studied.[26]

Altogether, given its material resources, its learned men, and its tolerant and interested atmosphere, there was no better place in America in the last quarter of the eighteenth century for the serious pursuit of science than Philadelphia.

III

The air of tolerance was not unimportant. Men's devotion to science in Philadelphia, as in England, was happily neither impaired nor deflected by those considerations which induced Continental scientists, especially the French, to point to the logical consequences of Newtonian physics for traditional theological concepts of the earth and man. Believing that their revelations demonstrated not only the wisdom but also the goodness of an all-powerful Creator, Newton and his immediate followers did not postulate a physical and mechanical cosmology. The same comprehensive ability to hold the old religion and the new science simultaneously was illustrated by the Philadelphians. In his address to the Philosophical Society in 1775, for example, David Rittenhouse refered to both God and Newton in terms equally acceptable to the followers of each. Considering the infinitude of the universe, he suggested that "all yonder stars innumerable, with their dependencies, may perhaps compose but the leaf of a flower in the Creator's garden, or a single pillar in the immense building of the Divine Architect." [27] Thus it was, concluded Timothy Matlack, referring to this remark in his address before the same Society a few years later, "that fair Science, while her right Hand guides and supports Man through the World, her left always points toward Heaven." [28] Thanks to the telescope, continued Owen Biddle in his oration of 1781, "the works of the Deity were no longer confined; this world, formerly so important, was reduced on the enlarged scale; and the power, goodness, and glory of the great and omnipotent Creator, was a theme that has made every sentimental heart to swell with hosannas unutterable." [29] In Philadelphia presumably a man might be both a Newtonian and an evangelical; like Owen Biddle, a mathematician and a great Friend. This British capacity to hold two logically incompatible ideas simultaneously Professor Dampier Dampier-Whetham attributes to the almost instinctive apprehension of a political people that there is much to be said on both sides of any question and that apparent differences may be resolved by further knowledge.[30] At any rate in the tolerant Quaker capital men advanced on their conquest of science without being harassed on flank and rear by forays from the theo-

[23] *Penna. Gazette*, May 1, 1782.

[24] Potts, Du Simitière . . . , *loc. cit.*, 350–351.

[25] *Penna. Gazette*, May 1, 1782.

[26] Sellers, Charles C., *The artist of the Revolution*, 272, 1939 (later published by the Amer. Philos. Soc. under the title Charles Willson Peale I, Early life, *Mem. Amer. Philos. Soc.* **23** (1), 1947); Smallwood, William M., *Natural history and the American mind*, 136–138, N. Y., Columbia Univ. Press, 1941.

[27] An oration, delivered February 24, 1775, before the American Philosophical Society . . . , in William Barton, *Memoirs of the life of David Rittenhouse*, 575, Phila., Edward Parker, 1813; Brasch, Frederick E., The Newtonian epoch in the American colonies, (1680–1783), *Amer. Antiq. Soc. Proc.*, n.s., **49**: 327, 1939.

[28] *An oration, delivered March 16, 1780, before . . . the American Philosophical Society . . .*, 7–8, Phila., Steiner and Cist, 1780.

[29] *An oration, delivered the second of March, 1781, at the request of the American Philosophical Society . . .*, 30, Phila., printed by Francis Bailey, 1781.

[30] Dampier-Whetham, W. C. Dampier, *A history of science and its relations with philosophy & religion*, 213–214, N. Y., Macmillan, 1931.

logical fortress, without being tempted to the wild joys of counter-attack.

Philadelphia had a tradition of tolerance; it had also a cosmopolitanism which provided a favorable atmosphere for scientific thought by linking Philadelphia with the centers of scientific activity abroad. Hardly a vessel left Delaware Bay for England or the Continent without someone bound for Europe; hardly one came up the river without at least one Philadelphian returning from a journey abroad. Among these trans-Atlantic travellers a small but articulate group were the young medical students. Though most of their time abroad was confined by professional studies, none failed to travel about in Europe a bit, and all brought back to Philadelphia some account of what they had seen and what they had heard talked of. Proud of their Americanism, they yet took much that Europe offered them. Their foreign experience and studies ushered them into the great world of science and letters and made the ablest of them citizens of the Enlightenment. In London Dr. John Fothergill, a friend of Franklin and America, and Dr. John Coakley Lettsom were genial and generous hosts in whose homes the Philadelphians met the Non-conformist culture and received, some of them, inspiration which directed their lives to the end. Dr. William Cullen in Edinburgh similarly made it a point to invite the young Americans to his table, where, after a good dinner, all kinds of professional, scientific, and literary questions were put, answered, and discussed. This acquaintance of the captains of American science with the abler lieutenants on the English side was of mutual advantage in the forward march of science and humanity in the eighteenth century.[31]

The association which the medical students thus began on a personal basis was continued through correspondence in the years after they returned to their homes. Between Philadelphia and London, Manchester, Edinburgh, Paris, and Milan a stream of books, pamphlets, and letters flowed seemingly without cease. In the manuscripts of Benjamin Rush alone are dozens and hundreds of letters from English and Continental physicians, men of science, and friends of liberty. One seeks election to the Philosophical Society; another sends some latest medical or scientific publication; a third requests information on the American Indians, the natural curiosities of the western country, or the effects of the climate of the United States.[32] One of Humphry Marshall's seed customers was Sir Joseph Banks; one of Gotthilf Muhlenberg's botanical correspondents was Professor Schreiber of Erlangen. From Perugia, Italy, taking "a phylosophical Liberty" with "a free American Philosopher," Adam Fabbroni sent in the care of Dr. George Logan two pamphlets for the American Philosophical Society and an offer to perform any service in Italy for Logan or "the celebrated Society."[33] The celebrated society itself was a kind of clearing house and American port of entry for scientific ideas; and the Philosophical Society maintained with European societies, and they with it, a communication which not even the war was allowed completely to disrupt.[34] In this work Dr. Franklin helped immeasurably, distributing the Society's publications abroad, bringing his scientific friends of two continents to a knowledge of it, and transmitting to it letters of scientific interest which he received from one or another of his many correspondents.

Utilitarian considerations provided a third favoring condition of scientific activity in Philadelphia in the latter years of the eighteenth century.

> Bright Science too, beneath our sacred dome,
> Shall find a last retreat, a fav'rite home,
> And, freed from schoolmen's trammels, shall impart
> Her cheering influence to each useful art,
> Diffuse her blessings, to the humblest cell,
> And with the lowliest peasant deign to dwell.[35]

While it is as imprudent as it is easy to overestimate utility as a factor in scientific progress in Philadelphia, it cannot be denied that a good deal of scientific work was undertaken for essentially practical purposes. Of the six standing commit-

[31] Bell, Whitfield J., Jr., Philadelphia medical students in Europe, 1750–1800, *PMHB* **67**: 1–29, 1943.

[32] The Rush correspondence is in the Library Company of Philadelphia, Ridgway Branch. See, for two examples only, Thomas Percival to Rush, Manchester, Sept. 19, 1786, and Charles Amoretti to Rush, Milan, April 8, 1786, Rush Mss., **28**: 55, **25**: 63. The Library Company is cited hereafter as LCP.

[33] Jan. 14, 1784. Logan Papers, **7**: 3, HSP.

[34] Article V of its legislative charter, granted in 1780, provided that, "whereas nations truly civilized (however unhappily at variance on other accounts) will never wage war with the Arts and Sciences, and the common interests of humanity," the Society might at all times, in war as in peace, correspond with learned societies and individuals of any nation or country whatever, on matters of interest to the Society, subject only to the inspection of the Supreme Executive Council of the Commonwealth. *Fundamental laws and regulations. . . .*

[35] W. I., Verses on the commencement of the year 1789, *Amer. Museum* **5**: 206–207, 1789.

tees of the American Philosophical Society, three were essentially practical in character. The charter granted to the Society in 1780 breathed faith in science as a promoter of the prosperity of mankind:

> The cultivation of useful knowledge and the advancement of the liberal arts and sciences in any Country, have the most direct tendency toward the improvement of agriculture, the enlargement of trade, the ease and comfort of life, the ornament of society, and the increase and happiness of mankind.[36]

Thanks to the mastery men obtain through science, declared Owen Biddle the next year, the conveniences of life are multiplied, and "we live in a state of improved ease, dignity, and opulence." [37]

That the sciences had a practical orientation was particularly evidenced in the cases of chemistry and botany. Both these sciences were held to be the handmaidens of medicine and agriculture; they were first formally taught in Philadelphia, as a matter of fact, in the Medical Department of the College by medical men. Dr. Moyes, for example, declared in 1785 that chemistry was almost wholly confined to medicine;[38] while Provost Smith, announcing the professorship of natural history and botany in the Medical Department, promised that "the philosophical parts of *Agriculture*, as they regard a science peculiarly interesting to these United States, will be . . . attended to." [39] "The man who will discover a method of preventing the fly from destroying turnips," the public was assured, "or who will point out a new and profitable article of agriculture and commerce, will deserve more from his fellow-citizens and from heaven, than all the Latin and Greek scholars, or all the teachers of technical learning, that ever existed, in any age or country." [40] Humphry Marshall accepted this estimation of values. In the preface of his *American Grove* he justified the study of botany on the ground that the importation and cultivation of foreign plants or the discovery of native productions of general usefulness would relieve the United States of dependence on foreign nations. Tea might be grown in the southern states; rhubarb deserved to be cultivated; while the discovery of a plant as useful as tobacco or the potato or of a substitute for coffee or quinine would be of inestimable advantage.[41] "The Science of Botany," Marshall went on in a paper to the Philadelphia Society for Promoting Agriculture in 1786, "certainly holds its most dignified station when subservient to Medicine; but its utility does not terminate in this alone, though it has too long been considered as having no other connexion." And he then showed the importance of botanical science to agriculture.[42]

Certainly not the least important of the bases of popular interest in science, especially in botany and natural history, was the romantic temper of the age. The rural scene was charming and the life of forest, field, and stream touched chords of sympathy in human breasts. The woods and fields were endowed with moods and feelings; and birds and animals were given sentiments and intelligence.[43] For whatever may have caused them to do so, Americans, like Europeans, were coming to view the natural world about them through lenses which colored the clearest objects, made simple things mysterious, and tangled ones straight. A man might look at a bird and classify it; he—more particularly his daughter—might clap his hands at the sight of it, however, call the bird redbreast, and write a poem on it. Nor was this view of nature confined to sentimental young men and women only. So completely a scientific spirit as David Rittenhouse, when he was running the western boundary of Pennsylvania in 1785, indulged his romantic fancy to his wife:

> I ever delighted in a wild uncultivated country; this is truly romantic, and, at this season of the year, beautiful and luxuriant in the highest degree. A few days ago, I walked up a little rivulet, in company with Mr. Ellicott, for a considerable distance, in order to enjoy the romantic scene. It was bounded on each side by steep hills of an immense height: its bottom was finely paved with large flag-stones, rising in steps, with, every now and then, a beautiful cascade. The further we went, the more gloomy and cool we found it. At last, I advised Mr. Ellicott that we should proceed no further; for, if we did,

[36] *Fundamental laws and regulations. . . .*

[37] *Op. cit.*, 36.

[38] Lectures, in William Martin, Lectures on Chymistry by Joseph Black, II: Feb. 18, 1785, Manuscript, HSP.

[39] A short account of the present state of the College, Academy and Charitable School of Philadelphia, Oct. 26, 1790, *Columbian Mag.* **5**: 275, 1790.

[40] A charge which ought to be delivered to the graduates in the arts, in all the colleges in the United States, *ibid.*, 78–79.

[41] *Arbustrum americanum: the American grove . . .*, vi, Philadelphia, printed by J. Crukshank, 1785.

[42] Observations on botany as applicable to rural economics, in William Darlington, *Memorials of John Bartram and Humphry Marshall*, 582–585, Phila., Lindsay and Blakiston, 1849.

[43] Woolley, Mary E., The development of the love of romantic scenery in America, *Amer. Hist. Rev.* **3**: 56–66, 1897.

we should in all probability find some of the water-goddesses,—perhaps stark naked and fast asleep. Mr. A*** went with us for company-sake; but neither the nymphs nor their shady bowers have any charms for him.[44]

What is significant here is that many persons who knew little and cared less for academic science were attracted to the trees where wood sprites danced and to the animal kingdom which was beyond the reach of constitutions and stay-laws and boundary lines. These romantics added little, to be sure, to scientific knowledge, but they performed the inestimable service of providing an interested audience for those who did.

IV

These favoring conditions of scientific investigation, however—tolerance, cosmopolitanism, utility, and romanticism—prevailed not only in Philadelphia, but throughout America and western Europe in the latter part of the eighteenth century. A few conditions, however, were uniquely American and one, at least, was uniquely Philadelphian.

In the first place, America was still a new country, hardly yet explored, not at all described. Like the residents of other sections of the country, the Philadelphians were impressed with the urgency to describe their own country scientifically. A hundred voices, foreign and domestic, called upon the American of scientific bent to look about him. Writing to Dr. Rush in 1784, Dr. Lettsom expressed the hope that America would now cultivate the arts of peace and he promised that this new land had "such an extent of novelty in . . . Soil, produce, improvement &c. as must stimulate genius, and gratify invention and study." [45] "Set your men of Science upon studying your own Country," he cried the next year, "its native and improvable productions—Your resources would influence Europe—your reflections would instruct her." [46] Dr. Lettsom was correct. No man of education or intelligence could cross Gray's Ferry and not see a dozen plants and trees unknown in Europe; or visit the Susquehanna and not find as many birds and animals native only to the American forests. European scientists begged for knowledge of these things; some few crossed the ocean to get it; but for the most part only the Americans could supply it. It was their opportunity, Provost Smith told the graduates of the College in 1790, to explore and describe the vast empire of the United States.[47] The meetings and collections of the Philosophical Society, to cite but a single example, enriched by fossil remains, bones of animals, and descriptions of the Indian mounds of the Ohio country, show how the challenge of western America to the sciences was answered.[48]

In the second place, American science, like American society, was marked by the War of the Revolution. The war interrupted scientific activity; the revolution gave it a special tone and direction. Amid the hostile clash of arms the arts and sciences are silent too. With the outbreak of hostilities, for example, the project to establish a colonial observatory in Philadelphia, with Rittenhouse public astronomer by royal appointment, came to nought; [49] while Rittenhouse himself, like Newton in the revolutionary settlement of 1689, was deeply involved in political matters. Though he did succeed in making some observations during the war years, the note Provost Smith penned in his copy of the first volume of the Philosophical Society *Transactions* aptly summarized the period:

> Astronomical observations, 1776: This year exhibiting little else but scenes of confusion and distress amidst the calamities of an unhappy war, scarce any attention was paid by members of the Philosophical Society to astronomical or any other literary subjects.[50]

Indeed not until after the British withdrawal from the city in 1778 were meetings of the Society resumed; not until 1785 did attendance climb back to normal again.[51]

Quite as serious as the diversion of thought and energy from scientific questions was the interruption of communication with England which the war entailed. After 1775 the flow of scientific communications from England to America dried to the merest trickle. Not even the new intel-

[44] Barton, *op. cit.*, 310–311.

[45] London, Feb. 28, 1784, Rush Mss., **28**: 4, LCP, Ridgway Branch.

[46] Sept. 7, 1785, *ibid.* **28**: 7.

[47] A charge to the graduates, *Columbian Mag.* **5**: 359–360, 1790.

[48] John Sullivan to American Philosophical Society, Phila., Feb. 16, 1781, APS Archives, Misc. letters, Box 1; Phillips, *op. cit.*, 123, 129, 146, 154, 169, 173; Thomas Jefferson to Charles Thomson, Paris, Sept. 20, 1787, *Writings* VI: 311–314, Memorial ed., 20 v., Washington, Thomas Jefferson Mem. Assn. of the U. S., 1903–1904.

[49] Nevil Maskelyne to Rev. Dr. Ewing, Greenwich, Aug. 4, 1775, APS, Ms. collections.

[50] Quoted in Samuel Alfred Mitchell, Astronomy during the early years of the American Philosophical Society, *Proc. Amer. Philos. Soc.* **86**: 16–17, 1942.

[51] Phillips, *op. cit.*, 87, 97, 100 *et seq.*

lectual contacts with France quite compensated for the loss. One of the severest taxes paid during the war by the medical profession, Dr. Rush told his old teacher Cullen on the reestablishment of peace, "was occasioned by the want of a regular supply of books from Europe, by which means we are eight years behind you in everything." The publication of Cullen's *First Lines of the Practice of Physick* in Philadelphia during the war, from a copy which found its way into the city, was accordingly a minor triumph for science.[52]

The war thus interrupted scientific activity; the revolution gave it new direction. A spirit of nationalism was abroad in the country which was injected into every consideration from dress and the anti-slavery movement to temperance and the sciences. Nicholas Collin argued it was the duty of philosophers "to cultivate with peculiar attention those parts of science, which are most beneficial to that country in which Providence has appointed their earthly stations";[53] and Rush expected much learning and many improvements to flow from the "harmony between the sciences and government."[54] Nationalism and local utility joined to reject technical and classical terms in science as "the remaining pedantic formality and fustian of dark antiquity, ill suiting the plain masculine independent genius of enlightened Americans."[55] After 1790 medical theses at the College of Philadelphia might be written either in Latin, as hitherto, or in "the language of the united states," the latter being defended by Rush as the likeliest means of diffusing medical knowledge.[56]

In medicine the new nationalism of the post-war period encouraged a good deal of thought and speculation, sometimes with startling results. Since there was a widely held belief that for every disease peculiar to America there was an American remedy, the search for native drugs was undertaken with spirit.[57] As early as 1789 the College of Physicians of Philadelphia circularized "the most respectable characters in the United States," asking their opinion of the need of an American dispensatory and particularly requesting information of all American remedies discovered anywhere in the country.[58] Dentistry was the republican art; it must be especially attended to in America, since premature loss of teeth was "a particular disadvantage in a great republic, where so many citizens are public speakers."[59] Rush and others argued the influence of political forms and events on the public health, now adducing evidence that republicanism and health are concomitant blessings, now that the strain of self-government produces various mental derangements.[60] Rush's new theory of therapeutics, with its emphasis on bleeding and heavy dosages, owed something to the prevailing nationalistic spirit; for diseases in America, Rush argued, are of a higher order than in Europe; in this strong, fresh, new America sick men are sicker and need more heroic treatment than do the enervated subjects of the worn-out monarchies of Europe.[61]

A final influence on the scientific activity of Philadelphians was uniquely Philadelphian in character. It was this, that as citizens of the metropolis Philadelphians considered themselves, as they were in fact by others considered, as in duty bound to stimulate, organize, and disseminate scientific learning. The first learned society in America, the Philadelphians' Philosophical Society, was looked to as the keystone of a grand edifice of science in America. As early as 1780, for example, Jeremy Belknap was looking from New England to Philadelphia for direction. Some means should be devised, he wrote Ebenezer Hazard, whereby properly qualified persons might search for natural productions. The Philosophi-

[52] Rush to Cullen, Phila., Sept. 16, 1783, *Jour. Chem. Educ.* **17**: 456, 1940. See also Rush to Lettsom, Phila., Nov. 15, 1783, in James J. Abraham, *Lettsom: his life, times, friends and descendants*, 367, London, W. Heinemann, 1933.

[53] An essay on those inquiries in natural philosophy, which at present are most beneficial to the United States of North America, *Trans. Amer. Philos. Soc.*, o.s., **3**: iii, 1793.

[54] Natural history of medicine among the Indians . . . , *Medical inquiries and observations* I: 168, 3rd ed., 4 v., Phila., Johnson and Warner, Mathew Carey *et al.*, 1809.

[55] "Dr. Plainsense," The pedantry of technical phraseology condemned, *Columbian Mag.* **1**: 805–807, 1787.

[56] An address delivered at the commencement held in the College of Philadelphia, *ibid.* **5**: 355–358, 1790.

[57] Rush, Natural history of medicine among the Indians, *loc. cit.*, 151; An eulogium of Dr. William Cullen, *Essays, literary, moral & philosophical*, 340–342, Phila., printed by Thomas and Samuel F. Bradford, 1798.

[58] Rush, A discourse delivered before the College of Physicians of Philadelphia, February 6th, 1787. On the objects of their institution, *Trans. Coll. of Physicians of Phila.* **1** (1): xx–xxi, 1793; Ruschenberger, W. S. W., *An account of the institution and progress of the College of Physicians of Philadelphia* . . . , 101–103, Phila., W. J. Dornan, printer, 1887.

[59] Collin, *loc. cit.*, iv.

[60] Rush, An account of the influence of the . . . events of the American revolution upon the human body, *Medical inquiries and observations* I: 232–243.

[61] Ramsay, David, *An eulogium upon Benjamin Rush, M.D.* . . . , 26–27, Phila., Bradford and Inskeep, 1813.

cal Society, he suggested, might do something in this way:

> or, if there were inferior societies, or boards of correspondents, in the several states, connected with the principal one at Philadelphia, and united in the same views, there might by such means be some valuable things brought to light, which, if discovered by individuals, are but imperfectly known, or neglected, or undervalued, or perhaps concealed, so as to be of no general use. Why may not *a Republic of Letters* be realized in America as well as a Republican Government? Why may there not be a Congress of Philosophers as well as of Statesmen? And why may there not be subordinate philosophical bodies connected with a principal one, as well as separate legislatures, acting in concert by a common assembly? I am so far an enthusiast in the cause of America as to wish she may shine Mistress of the Sciences, as well as the Asylum of Liberty.[62]

A proposal that the members of the Philosophical Society in each state be formed into local committees to forward the Society's business was in fact actually presented and considered in Philadelphia in this same year, but nothing came of it.[63] Still, although no federation of learned societies was effected in eighteenth century America with its seat at Philadelphia, the scientific, medical, and agricultural societies of the Quaker City were actually looked to by those in New York, Charleston, Providence, and other places for advice and assistance.[64]

And so it fell out that Philadelphia was hailed at the close of the eighteenth century as fair science's seat. The city was already the Athens of the West; it expected one day to become the Athens of Mankind. In the great chorus which swelled in praise of the new state just risen on the shores of the western continent science, liberty and humanity were all blended together. The true patriot appreciated learning and encouraged it as the promoter of every blessing; the true philosopher understood that liberty too is a polar truth and the essential condition of the progress and happiness of mankind. "Patriotism and literature," said Dr. Rush, "are here connected together; and a man cannot neglect the one, without being destitute of the other."[65] In some graduation verse spoken at the commencement of the College in 1790 science kept the honored company in which Philadelphians were accustomed to find her:

> . . . to earth's end fair Science shall encrease,
> And form one reign of KNOWLEDGE and of PEACE;
> Where pure RELIGION's precepts shall prevail,
> Impartial JUSTICE poise her balanc'd scale.
> Bright LIBERTY exulting in each breeze,
> Innoxious PLEASURE, *philosophic* ease,
> Heart-cheering MIRTH, and PLENTY ever-gay,
> And rosy HEALTH—shall all attend her sway.[66]

[62] Feb. 4, 1780. Belknap papers, *Mass. Hist. Soc. Colls.*, 5th ser., **2**: 255.

[63] APS Minutes, Dec. 15, 1780, Ms., APS; Lewis Nicola to APS, read April 7, 1780, APS Archives.

[64] See, for example, Mills, William Hayne, The relation between the Philadelphia Society for Promoting Agriculture, organized Feb. 11, 1785 and the Agricultural Society of South Carolina, organized August 24, 1785, a manuscript in the Papers of the Philadelphia Society for Promoting Agriculture in the University of Pennsylvania School of Veterinary Medicine Library.

[65] Natural history of medicine among the Indians, *loc. cit.*, 168.

[66] An exercise, performed at the public commencement, in the College of Philadelphia, July 17, 1790, *Columbian Mag.* **5**: 49–57, 1790.

THE DISCOVERY OF AN OIL FIELD

PAUL D. FOOTE

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(*Read November 20, 1947*)

THE discovery of an oil field represents the coordinated efforts of a large group in many divisions of an oil corporation, involving the executive, legal, and technical departments, and since an oil field is not actually discovered until proven by the drill, all phases of production activity are concerned. The historical geologist delineates a general area of interest; concessions and leases must be secured; surface and subsurface geology is explored as far as possible; and geophysical crews are dispatched to the scene of operations.

This paper is concerned with the geophysical phase of a development that has led to the discovery of what may be the largest oil field in the world. Although the geophysicist has played a prominent role in the achievement, the contributions of the other professions in no way should be subordinated. This only emphasizes, at least as far as petroleum is concerned, that the day of the isolated prospector is over. The discovery of an oil field cannot be credited to an individual or to a single profession. Petroleum exploration is a highly organized group activity.

The primary requirements for an oil field are: proximity to suitable source beds of shallow marine origin containing organic material; a rock stratum of sufficient porosity to serve as a reservoir; and some kind of a trap in this rock, either structural or stratigraphic, in which gravitational separation of water, oil, and gas may occur.

Besides the many smaller geologic basins distributed throughout the world, there are at least two gigantic basins in which great thicknesses of fine-grained marine sediments are interbedded with thick, porous sandstone and limestone strata. One of these surrounds the present Gulf of Mexico and the Caribbean, and the other borders the Persian Gulf. Although about half of the world's cumulative petroleum supply so far has been produced from the American basin, the Persian Gulf basin will undoubtedly prove to be the more productive area. This basin is approximately 1,600 miles long and 500 miles wide, or about twice the size of all our Gulf Coast States, and is filled with sedimentary rocks to a depth of 30,000 feet or more over large areas. During the period when the mountains on the north and the northeast were developing, the sedimentary deposits in the basin were compressed and wrinkled like a washboard with the formation of numerous traps, all of which are potential oil fields. The problem of locating traps at depths of a mile and more, especially when there is no surface expression, falls within the province of exploration geophysics. This highly developed science is scarcely twenty-five years old but today represents an operating budget of a hundred million dollars annually for the American petroleum industry and a very considerable additional sum for mineral and mining exploration.

Of the numerous types of trap the petroleum geophysicist is required to delineate, only the most simple anticlinal structure will be described, since this is sufficient for the illustration of the operating techniques employed without introducing the complication of difficult structural or stratigraphic situations actually encountered in routine operations.

Let us assume that we are exploring an unknown area where the surface of the ground is flat, or at least gives no suggestion of the subsurface structure, and that we are attempting to discover an anticlinal trap such as shown in cross-section by figure 1, and in subsurface contours by figure 2. If a structure of this type can be discovered in

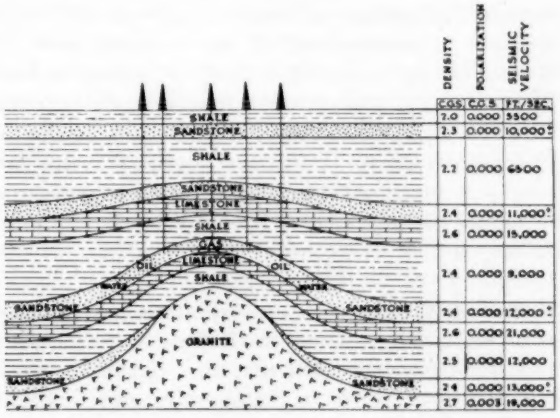

FIG. 1. Simple geologic structure with oil field.

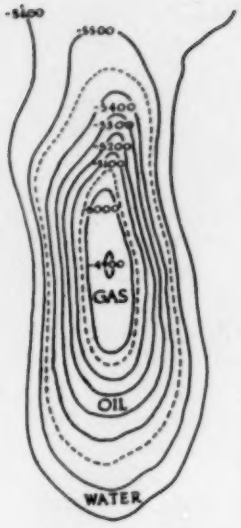

FIG. 2. Contours on producing sand horizon of structure shown in figure 1. Depths are in feet below sea level.

an area not too far removed from organic source beds, as predicated by the historical geologist, we have the possibility of an oil field. Three principal exploration techniques are available: employing the magnetometer, the gravimeter, and the reflection or refraction seismograph.

The magnetic polarization of sediments is usually small compared to that of the underlying basement consisting of igneous complex such as granite and gabbro. Hence a magnetic survey either of the vertical component or total intensity of the earth's magnetic field reflects a basement picture. The anomalies portrayed by a contour map, i.e. lines of equal magnetic intensity, are due to structure in a basement of uniform polarization, or to changes in composition of the basement with resulting changes in polarization, or in part to both. Now it is a well known principle of potential function theory that there are an infinite number of interpretations of subsurface conditions that will satisfy a given set of surface measurements, but in actual practice only a few of the many possible solutions may be geologically reasonable. By the utilization of all known geological and physical data for the area, obtained from independent sources, and by various mathematical devices, it is possible to interpret the magnetic data in terms of the probable basement topography and finally to obtain a rough regional map representing depth to granite or the thickness of sedimentary column. The anomalies on this map that are attributed to structure in the igneous complex may then be explored by other more costly and precise methods to determine whether or not they are reflected in the upper sandstone and limestone horizons. For the hypothetical structure illustrated by figure 1, the magnetic anomaly, as shown in figure 3, amounts to about 90 gamma or $90 \cdot 10^{-5}$ gauss. Actually the granite uplift postulated is an order of magnitude larger than one that would be ordinarily significant from the standpoint of petroleum exploration. Magnetic anomalies of 10 gamma and less are characteristic of oil structures produced by basement disturbances, and hence the precision of measurement must be about 10^{-5} gauss for satisfactory interpretation.

Formerly magnetic measurements were made on the surface of the ground using various modifications of the Schmidt vertical balance, but this procedure has been entirely changed with the development by our laboratory of the airborne magnetometer (fig. 4). The bird trailing the plane contains the pick-up mechanism which is a magnetic flux-responsive device automatically oriented, by servo-control mechanism, in the direction of the magnetic vector, regardless of the motion of the plane. The electrical impulses are transmitted to apparatus located within the plane (fig. 5) by which a record of all variations in the total magnetic intensity is drawn on a continuous chart. At the same time, the position of the plane relative to the ground is registered by continuous automatic triangulation survey from two base stations, through the use of radar.

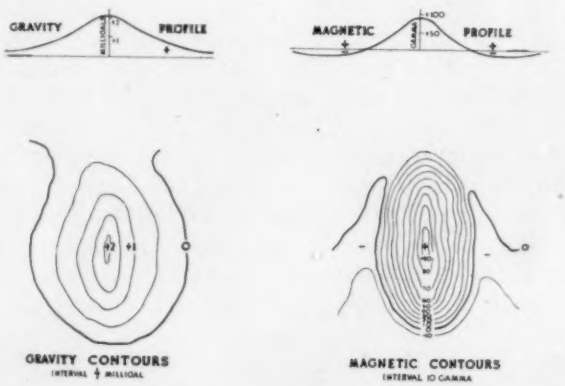

FIG. 3. Gravity and magnetic surveys over structure shown in figure 1. The gravity contours represent lines of equal weight. The magnetic contours are lines of equal vertical intensity of the earth's magnetic field. The picture would be somewhat different on the basis of total magnetic intensity as measured by the flying magnetometer.

FIG. 4. The Gulf flying magnetometer. The pick-up mechanism is located in the bird trailing the plane at the lower left hand corner.

The complete equipment for this type of work is very costly but has the advantage that precision surveys can be made over water and inaccessible terrain at speeds from 150 to 200 miles per hour. More data may be secured in a few hours than are possible in months of work with a ground crew. Surveys may be conducted at any height above the surface and the effects of erratic disturbances, such as volcanics and magnetic gravel, are eliminated.

The second basic method for locating buried structures involves an application of Newton's Law that the gravitational attraction of matter depends upon its mass and the distance from the observer. The earth's gravitational field is distorted wherever rock strata of varying densities have been folded and deformed by geologic movements. As in all geophysical exploration, precision

FIG. 5. Interior view of the flying magnetometer showing some of the amplifying and recording apparatus.

FIG. 6. A group of gravimeters used in exploration work.

and speed are of primary importance, the latter in order to reduce operational costs. The Eötvos torsion balance was used extensively until about 1930. The time required for a single station was eight hours and through instrumental improvements this was finally reduced to four hours. With our development of the pendulum, the time for a single gravity observation was decreased to thirty minutes. Our gravimeter became a practical instrument in 1932 and today measurements are made in the field to a precision of one to five parts in 100,000,000 in from one to three minutes. The gravity anomaly for the large structure of figure 1 amounts to two milligals as shown in figure 3, a disturbance of the gravitational field of roughly two parts in a million. The contours here represent lines of equal weight. In spite of the extreme sensitivity of the gravimeter, it can be transported in an ordinary light truck, and a small model has been developed for use on horseback or for hand portage. It is also employed for underwater surveys by means of semiautomatic remote controls communicating with personnel on the deck of the ship.

Figure 6 shows several of the larger type of gravimeter, and figure 7 illustrates the mechanism by which they operate. This is merely a spring with a weight on the lower end. If gravity increases at a certain place, the spring elongates. Now a major oil field represents a gravitational anomaly in general of the order of one's fractional change in weight on this floor and the next floor above. Simple computation shows that the spring is accordingly elongated by an amount that is smaller than the resolving power of any viewing microscope and hence is visually undetectable.

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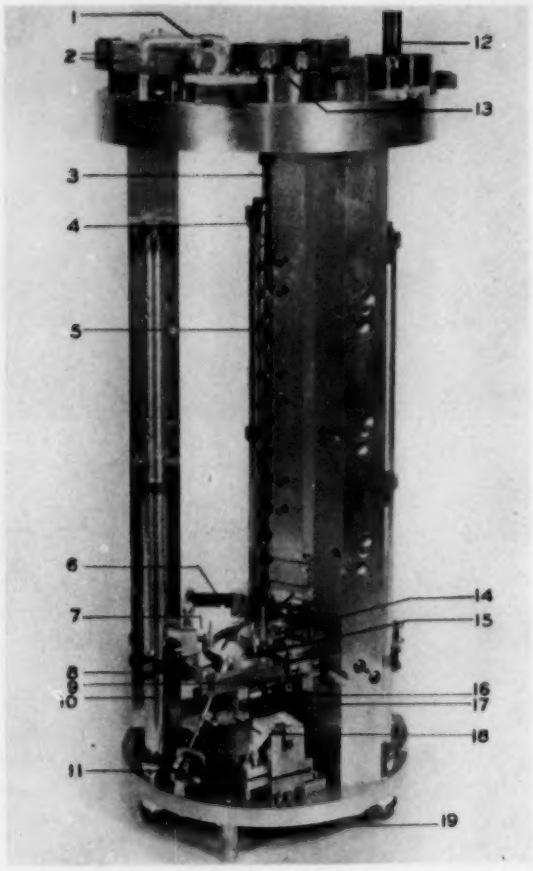


FIG. 7. Interior mechanism of the Gulf gravimeter.

To overcome this difficulty of measurement, the spring is so constructed of special prestressed material that linear motion is converted into angular rotation which may be readily amplified by optical mirrors. The surprising feature in this development is the constancy of the physical properties of the thermostated spring. Its length must be reproducible over a series of observations to within the diameter of seven atoms of metal to account for the precision obtained in the closure of the field surveys.

Theoretically the interpretation of a gravity anomaly is subject to the same limitation regarding the uniqueness of the solution that is characteristic of any potential function problem. However in general we have much more accurate geological subsurface data on density contrasts than exist for polarization. Accordingly, with precise gravity measurements on the surface, it is often possible to detail the form of a buried structure with considerable accuracy, sufficient to justify the drilling of a costly wildcat well. When gravity measurements as small as a few parts in 100,000,000 are made, the effects of the tidal forces that arise from the sun and moon, and other sources, are readily observable. Figure 8 shows the variation of tidal effects at several stations made simultaneously with our gravimeters. Since the tidal forces have incommensurable periods, the curves are not exactly reproducible in time but a definite maximum occurs every twelve hours. On the day on which these data were obtained, a woman in Louisiana, interested in reducing and weighing 150 pounds at 5 A.M., would weigh 149.999955 pounds six hours later. All of us have our minimum weight at noon or midnight on the day of the full moon, but the effect, as far as reducing is concerned, is of merely academic interest.

The third basic method of geophysical exploration involves the use of the seismograph. Figure 9 shows schematically the equipment required for reflection work. A small charge of gelatin is exploded below the weathered layer of the surface and the compressional wave travels down to a good reflecting horizon such as limestone, and is picked up at the surface by a series of perhaps 80 equally spaced detectors. These instruments are actuated by the vertical velocity of the movement of the

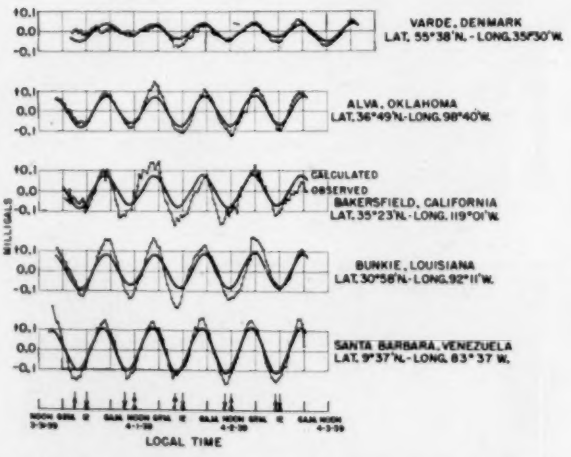


FIG. 8. Diurnal gravity measurements made simultaneously at several points of different latitude. Lunar and solar noon and midnight are indicated on the lower line. The observed effects are definitely larger than the values calculated and phase relations vary somewhat with both latitude and longitude. These variations are of interest in studies of the earth's rigidity and tidal effects on land. The tidal forces are ripples on the total force diagram, the zero of which on this scale of plotting would extend some 15 miles below the page.

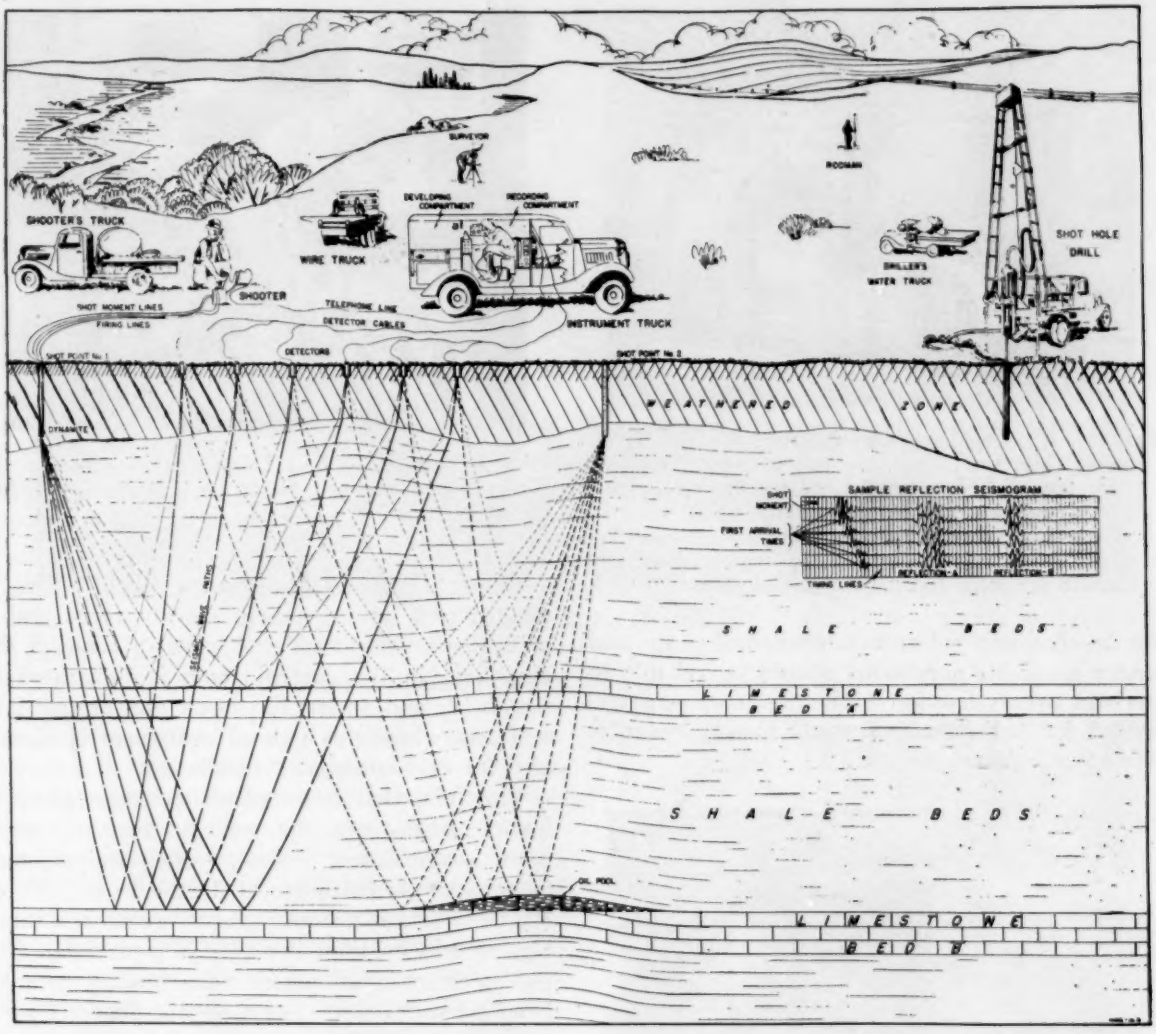


FIG. 9. Schematic drawing of the equipment layout for seismograph reflection shooting.

earth, at a selected frequency, produced by the reflected wave. This exceedingly small quantity is amplified by an astronomical figure through the use of electrical equipment within the truck, and is recorded on photographic paper. A record for the simple structure we have been discussing is shown by figure 10. The average velocity of sound for the path under consideration and its variation with depth and regional area may be determined by independent experiments. The record shows the time required for the entire path of the wave. Hence the depth to a given point on the reflecting horizon, with minor corrections, is one-half this time multiplied by the average velocity. Such a procedure is continued at short intervals over a surface network until sufficient data are obtained

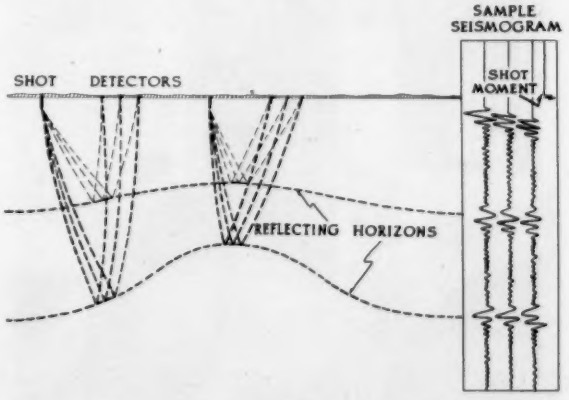


FIG. 10. Wave path for reflection shooting over the structure of figure 1 and theoretical seismogram showing two prominent reflections.

FIG. 11. A seismograph instrument truck. This is divided into two rooms, the one in front containing the instrumental equipment and the one in the rear with complete photographic dark room facilities. Telephone or radio communication is maintained between the various units of the seismograph party which are often spread over several miles.

for a complete subsurface structural map that under favorable conditions should be reliable to perhaps twenty-five feet. The final map so determined for our structure would closely resemble the actual contours of figure 2.

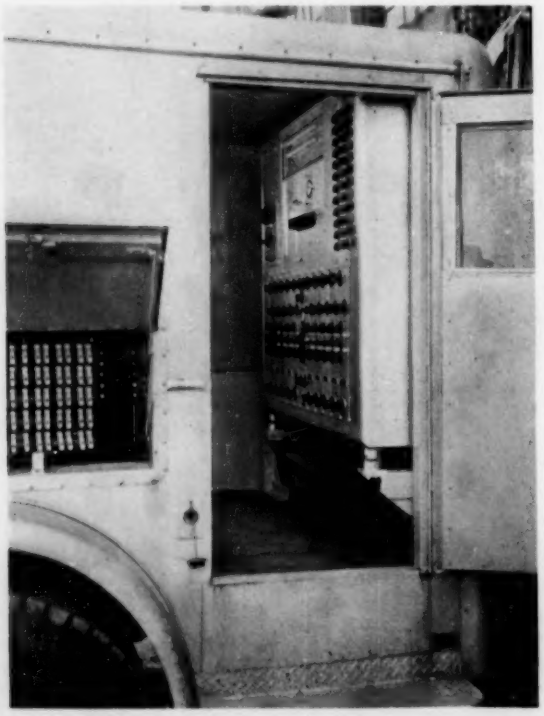


FIG. 12. Some of the amplifier and recording equipment in a seismograph instrument truck.

FIG. 13. Calibration and adjustment of some of the equipment mounted inside the seismograph instrument truck.

Figure 11 shows a recording truck. This is divided into an instrument control room and a photographic darkroom. A view of some of the amplifiers in the control room is illustrated in figure 12, and figure 13 shows one of our laboratories where this type of equipment is assembled for calibration and installation.

The refraction seismograph technique depends for its success upon the usual presence of one or more consolidated, elastic, widely-spaced rock layers such as limestone at depths from 3,000 to 10,000 feet, that transmit seismic waves at a much higher velocity than the overlying section. The pickup detectors are placed from three to ten miles from the shot point. Some seismic energy travels downward to the high velocity layer, along it, and back to the surface by a path such as illustrated

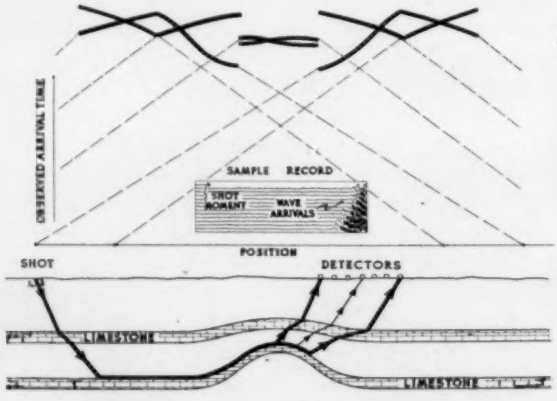


FIG. 14. Schematic refraction seismogram over structure of figure 1.

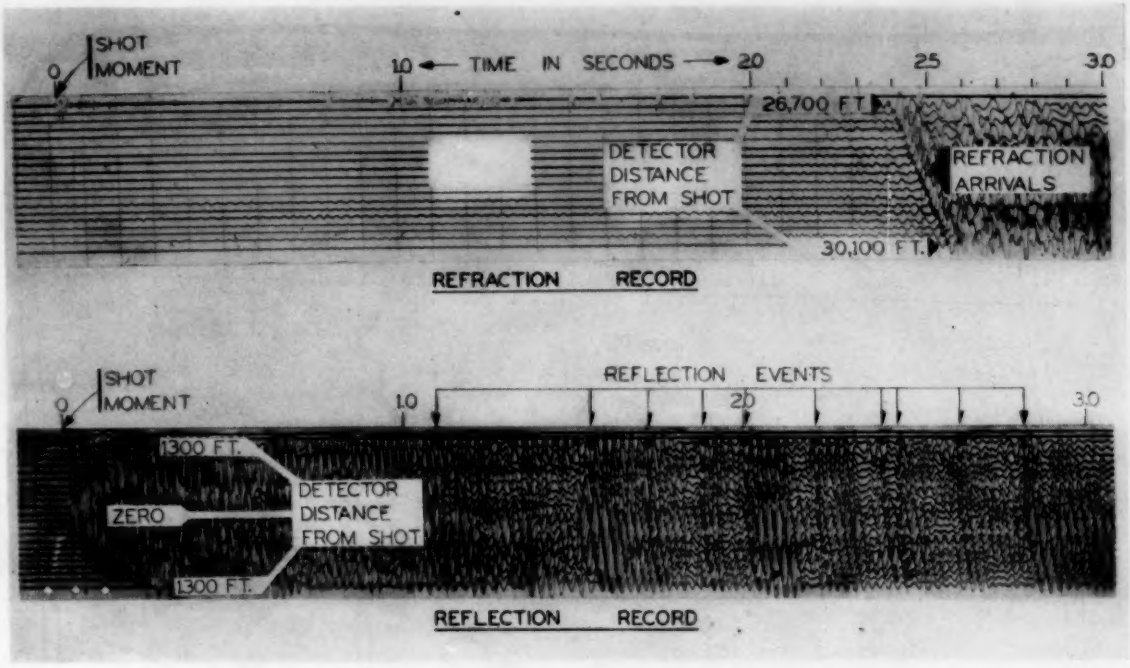


FIG. 15. Actual refraction and reflection seismograms.

in the lower half of figure 14. When the spread distance is large, this path, because of the high velocity, represents a first arrival of the compression wave. Recordings are made with a multiplicity of spaced detectors for each shot. In the upper half of figure 14, each heavy line segment represents measured arrival times plotted at detector positions with the positions of associated shot points being located at the opposite ends of the dashed lines. The shape of these arrival-time curves permits unique determinations of the depth, dip, and characteristic velocity of the buried rock layer. When the survey is extended over a considerable surface area, a structural map may be prepared for any deep high velocity subsurface

FIG. 16. Interpretation of geophysical field records.

FIG. 17. A geophysical crew leaves the laboratory for service in a foreign field.

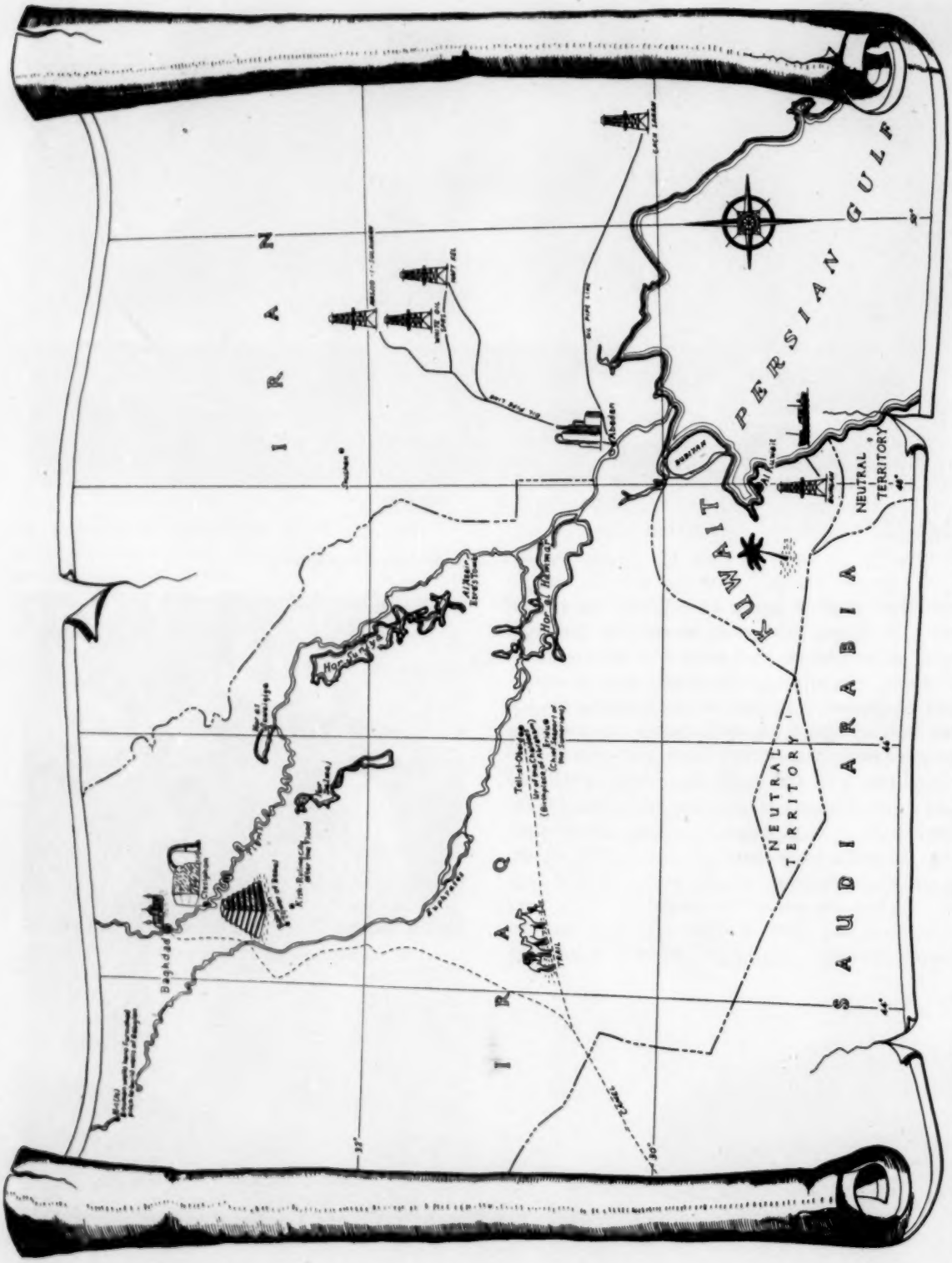


FIG. 18. Map of the historic area surrounding Kuwait. The Burghan field is indicated by an oil derrick at the northwest edge of the Persian Gulf.

FIG. 19. Geophysical party headquarters on the desert.

horizon. Again, such a map would resemble figure 2.

We have considered only the most simple type of geologic structure. Actually every change in lithology gives rise to reflected and refracted energy so that the reflection and refraction records actually obtained in field work are very complicated, as shown in figure 15. Similar difficulties arise in all types of geophysical work which accounts for the fact that we have over one hundred persons engaged in the disentangling of the data and their interpretation in terms of geologic structure. Several of this hard-working group are shown in figure 16.

With equipment of the type described, except for the flying magnetometer that was not developed at this time, a geophysical party left the laboratory (fig. 17) and arived at Kuwait at the head of the Persian Gulf (fig. 18) where, in a few months, possibly the largest oil field in the world was discovered. Figure 19 shows the geophysical camp in the desert. During a single winter season, the entire country of Kuwait was covered by a complete checkerboard of magnetic and gravity measurements. The structure finally selected was confirmed by the reflection seismograph and is now known as the Burghan anticline.

The oil field covers a producing area of perhaps 75 square miles and so far each well drilled to a depth of around 4,000 to 5,000 feet is capable of producing several thousand barrels a day from the Cretaceous. It is too early to make an estimate of the potential recovery but it now appears that this single field will produce at least half as much as the known reserves in all of the 3,180 oil fields in the United States. Possibly 500 wells in Kuwait will produce half as much oil as the 425,000 wells in our own country.

Kuwait is a desert about the size of Delaware, with two small oases and a few scattered wells yielding brackish water (fig. 20). Drinking water is imported in large boxes from the mouth of the Tigris and is distributed at high cost in goatskins. About 50,000 people live in the city of Kuwait; the rest are wandering nomadic sheep and camel herders known as Bedouins. Temperatures rise

FIG. 20. One of the few water wells, all of which furnish brackish water of rather high salt content.

FIG. 21. Men of affairs—Kuwait.

to 130° F. in summer. Blades of grass come up through the sandy soil during the feeble winter rains and if not eaten turn to wisps of hay that become the food for sheep. The inhabitants live in a medieval atmosphere (fig. 21 and fig. 22) and most of them are undernourished. Trachoma is universal because of scarcity of wash water and lack of sanitation. Amoebic dysentery and social diseases are prevalent. In spite of these handicaps, the people are intelligent in their native way, willing to work, absolutely honest and friendly.

Into this poverty-stricken, God-forsaken country comes the geophysicist with the touch of Midas. The metamorphosis is completed with the construction of pipe lines, refineries, homes, clubs, theaters, stores, hospitals—all completely air-conditioned; when water works and sewage systems are installed and a modern sanitary city for the army of employees and their families is created on the desert soil.

The Persian Gulf geologic basin was the center of world culture some 5,000 years in the past. Only a few miles northwest of Kuwait, the Sumerian civilization flourished and has left us with

FIG. 22. Typical boat-building industry—Kuwait.

the earliest recorded history of intelligent mankind. Just over the western edge are located the ancient gold mines that were worked with slave labor by King David and King Solomon. And then, for some reason, the area deteriorated and civilization declined.

The discovery of petroleum in this empire of oil is bringing about a renaissance. Kuwait is destined to become an important influence in world affairs, a center of aeronautical and oceanic transportation, and certainly a focal point for international power politics. Many of the so-called "have-not" nations, which in general are have-nots for the same generic reason that the unemployed are often unemployable, suddenly are vitally interested in the social welfare of this general area. These groups are always more concerned with the redistribution of the wealth of other people than with the independent creation of wealth by their own discovery and effort. Even the desert soil of Kuwait appears to be fertile if water can be brought in from the Euphrates district for irrigation, a project financially possible through royalty oil. The country may become a prosperous Garden of Eden; overproduction may occur. This will afford another opportunity for a planned economy. A Kuwaitian New Deal develops. The people will be forced to plough-under the fields, to slaughter the lambs, to increase subsidies and taxes, thereby lowering the standard of living again, and completing the cycle to poverty.

BENJAMIN RUSH AS A PROMOTER OF USEFUL KNOWLEDGE*

LYMAN H. BUTTERFIELD

Assistant Editor, The Jefferson Papers, Princeton University

(*Read November 20, 1947*)

"THE education of a physician," said Dr. Rush in concluding a course of medical lectures in 1789, "gives him a peculiar insight in the principles of many arts, and the practice of physic favours his opportunities of doing good, by diffusing knowledge of all kinds."[1] In Rome, Rush went on to observe, where medicine was practised only by slaves, physicians were condemned by their profession to practise "the mute art," but the physician-citizen of a free republic disdains "an ignoble silence" and takes an active part in promoting the progress of his country and his kind. Probably not one among Rush's listeners was unaware that the lecturer addressing them had signed the Declaration of Independence, was a power in Pennsylvania politics, and stood second only to Dr. Franklin in the instigation and support of projects for advancing the happiness of his countrymen.

There was little in Benjamin Rush's early background that foreshadowed this dedication to public and practical causes. Like Franklin, he was reared in the pious, dissenting way; but, unlike Franklin, he was sent on to a strict Presbyterian school kept by an uncle who was an eminent clergyman and later president of Princeton College, where Rush took a degree in 1760. His training under Finley and Davies, in the shadow of the greatest of the Calvinist doctors, Jonathan Edwards, of course instilled in him a searching conscience. When, as a medical apprentice in John Redman's shop, he described his life and prospects to a former classmate, he deprecated the worldly vocation he had chosen:

> Now how inglorious must this Study Appear when set in Competition with Divinity, the one employed in advancing temporal Happiness the other eternal,—One applying Remedies to a fading, mortal Body—the other employed in healing the Sickness of a Soul: immortal & everlasting.[2]

To this Rush subjoined some morose reflections on the wickedness of city life—in Quaker Philadelphia!

"Temporal happiness" seemed a paltry objective for human effort at this stage of Rush's development. But though he was to remain all his life in certain respects a clergyman *manqué*, his three-year sojourn in Europe greatly altered and widened his intellectual horizon. Edinburgh, where he spent two years, was a focus of European culture and scientific activity in the 1760's. Rush met philosophers and medical and literary men of the first stature there, debated in the faculty-student scientific society, and wrote home letters vibrant with the revolutionary hopes of the Enlightenment.[3] He chose to concentrate upon the study of chemistry, partly because the chair in that subject was not filled in the new medical school in Philadelphia and Rush hoped to obtain it, and partly because, as he told a friend at home, he would thus best qualify himself to help in establishing new industries in Pennsylvania.[4] But even in common social intercourse in Edinburgh Rush found a lively curiosity about the phenomena of the temporal world that helped to convert him into a "philosopher"—as the eighteenth century understood the term. There is extant a diverting letter written to the same Philadelphia friend requesting him to gather and send a collection of "as many of our American Curiosities as

* The author, who is a Library Research Associate of the Society, wishes gratefully to acknowledge the aid of a grant from the American Philosophical Society for the purpose of gathering and editing the letters of Benjamin Rush.

[1] Observations on the Duties of a Physician and the Methods of Improving Medicine. Accommodated to the Present State of Society and Manners in the United States, delivered Feb. 7, 1789; in *Medical Inquiries and Observations*, 2nd ed., I: 392, Phila., 1805.

[2] To Enoch Green, 1761; MS., Hist. Soc. of Penna., Gratz Collection.

[3] Relatively few of these letters, among many written, survive. See especially the series to Dr. John Morgan, 1766–1768, the earliest of which is in the Historical Society of Pennsylvania, Gratz Collection, and the others in the College of Physicians of Philadelphia. The latter are extensively quoted in Joseph Carson, *A History of the Medical Department of the University of Pennsylvania*, 23 ff., Phila., 1869.

[4] To Thomas Bradford, Apr. 15, 1768; MS., Amer. Philos. Soc.

you can," including stuffed ground and flying squirrels, mocking and humming birds, some Indian wampum, "and whatever else will be admired here as a Curiosity," to be directed to Mr. John Caw, a wealthy and amiable Scot, "who would willingly sacrifice an Estate in enriching his Museum." [5]

From Edinburgh, Rush passed in the fall of 1768 to the hospitals and anatomical theaters of London, and from there to Paris, where he had time only to see the sights, of which he kept a conscientious record swelled out with reflections of a quasi-philosophical character. In both capitals he was introduced into circles of learning and taste, but by all odds the most influential relationship he formed on his grand tour was with a fellow-Pennsylvanian, Benjamin Franklin. In the inspired way that he had with younger people, Franklin recognized the promise of Rush's talents and drew them out. It was he who financed Rush's jaunt to Paris; and the loan was repaid with the first fees Rush earned in private practice.[6] They promptly fell into a correspondence which embraced such subjects as the causes of colds, the chemical discoveries of Joseph Priestley, and ballooning. Rush's early letters to Franklin bristle with cases and authorities. A good example of his habits and thinking in philosophical investigations during his first years in practice is found in a letter replying to Franklin's speculations on colds:

> I have met with many Facts which confirm your Opinion of the Origin of Catarhs from Cloaths—Beds—Books &c. Baron Vanswieten in his last Volume of Commentaries on Dr. Boerhave's Aphorisms in treating upon Epidemic Diseases mentions with Astonishment a Disorder which was peculiar only to the Students & Bookseller of the University of Alstorp in Switzerland. May not the Origin of this be traced to the Library of the University from which all the Inhabitants of the town except the Bookseller were probably excluded? [7]

Whatever this reveals about eighteenth-century standards of library service, it is evident that Rush was groping toward a twentieth-century explanation of allergic phenomena.

After Franklin's return to America, Rush saw him frequently and was his collaborator in numerous public causes. It is a loss to literature that the younger man never carried out his project of compiling a book of "Franklinia," materials for which are scattered through his notebooks in the Library Company of Philadelphia.[8]

Rush had returned to Philadelphia in the summer of 1769 determined to contribute to the advancement of arts and sciences in America. Somewhat rhetorically, he wrote one of his pupils a year or two before the Revolution broke out: "Medicine is my wife; science is my mistress; books are my companions; my study is my grave: there I lie buried, the world 'forgetting, by the world forgot.'" [9] And since, as he later said, "the science of medicine is related to every thing," [10] his observations and speculations were circumscribed by no boundaries whatever. Apart from clinical medicine, his letters, essays, and lectures deal with subjects as diverse as psychiatry and forestry, animal husbandry and steam navigation, penology and archaeology. With Priestley he corresponded on chemistry, with Jefferson on public health, with Ellicott on exploration, with Lettsom on botany, with Pickering on Indian ethnology, and with Price on education. These subjects and names are chosen almost at random. It is not surprising that he was charged with "polygamy" in his studies. To this his retort was: "Unlike a plurality of wives—my studies all agree, & are handmaids to each other." [11]

All of these subjects came within the purview of the American Philosophical Society, and most, if not all, of the correspondents I have named were members of it. Rush became a member of the Society in 1769 by virtue of his membership in the American Society held at Philadelphia for Promoting Useful Knowledge, to which he had been elected February 26, 1768, while abroad. The Minutes of that date contain an instruction

[5] To Thomas Bradford, Feb. 12, 1767; MS., Haverford College Library, Roberts Collection.

[6] Franklin to Messrs. Smith, Wright & Gray, Feb. 13, 1769; MS., Amer. Philos. Soc., Franklin Papers; Louis A. Biddle, ed., *A Memorial containing Travels through Life or Sundry Incidents in the Life of Benjamin Rush. . . . Written by Himself*, 49, Lanoraie, privately printed, 1905.

[7] Undated [1771?]; MS., Amer. Philos. Soc., Franklin Papers.

[8] Ramsay, David, *An Eulogium upon Benjamin Rush, M.D. . . .*, 99, Phila., 1813. Some of the notes for the book were printed in *Penna. Mag. Hist. Biog.* **29**: 23–28, 1905.

[9] Undated letter [1773 or 1774] to Ramsay, quoted in Ramsay's *Eulogium*, 131.

[10] *Sixteen Introductory Lectures, to Courses of Lectures upon the Institutes and Practice of Medicine . . .*, 295, Phila., 1811.

[11] Commonplace Book, 1792–1813; MS., Amer. Philos. Soc.

to Dr. John Morgan to write informing the several new members of their election and to "let them know that the Society expect to be favoured with their sentiments on such subjects as fall under their notice or observation, that are curious or useful and tending to promote the ends which the Society have in view." Those ends have been often set forth, but never more plainly than in the preface to the first volume of the Society's *Transactions*, issued in 1771:

> Knowledge is of little use, when confined to mere speculation: But when speculative truths are reduced to practice, when theories, grounded upon experiments, are applied to the common purposes of life; and when, by these, agriculture is improved, trade enlarged, the arts of living made more easy and comfortable, and, of course, the increase and happiness of mankind promoted; knowledge then becomes really useful. That this Society, therefore, may, in some degree, answer the ends of its institution, the members propose to confine their disquisitions, principally, to such subjects as tend to the improvement of their country, and advancement of its interest and prosperity.

A clubbable man, a patriot, and a philosopher, Rush was well prepared to join in such a program. Never living more than a few blocks away, he was a frequent attendant at the meetings in Philosophical Hall during the rest of his life; and from 1770 onward, except for two intervals, he held office in the organization, serving successively as Curator (1770–1772), Secretary (1773–1776), Vice-president (1797–1800), and Councilor (1786–1794, 1806–1813). Between 1770 and 1797 he delivered fifteen papers and orations before the Society, most of which were published in the first four volumes of the *Transactions* or separately under the Society's auspices. A list of these is appended to this article. In substance the papers range from inquiries into the nature of sleep and dreams, mineral springs in Philadelphia and vicinity, old age, and methods of preventing the effects of cold upon the human body, to "Thoughts on Common Sense," "An Account of the Sugar-Maple Tree of the United States," and "Observations intended to favour a supposition that the Black Color (as it is called) of the Negroes is derived from the Leprosy."

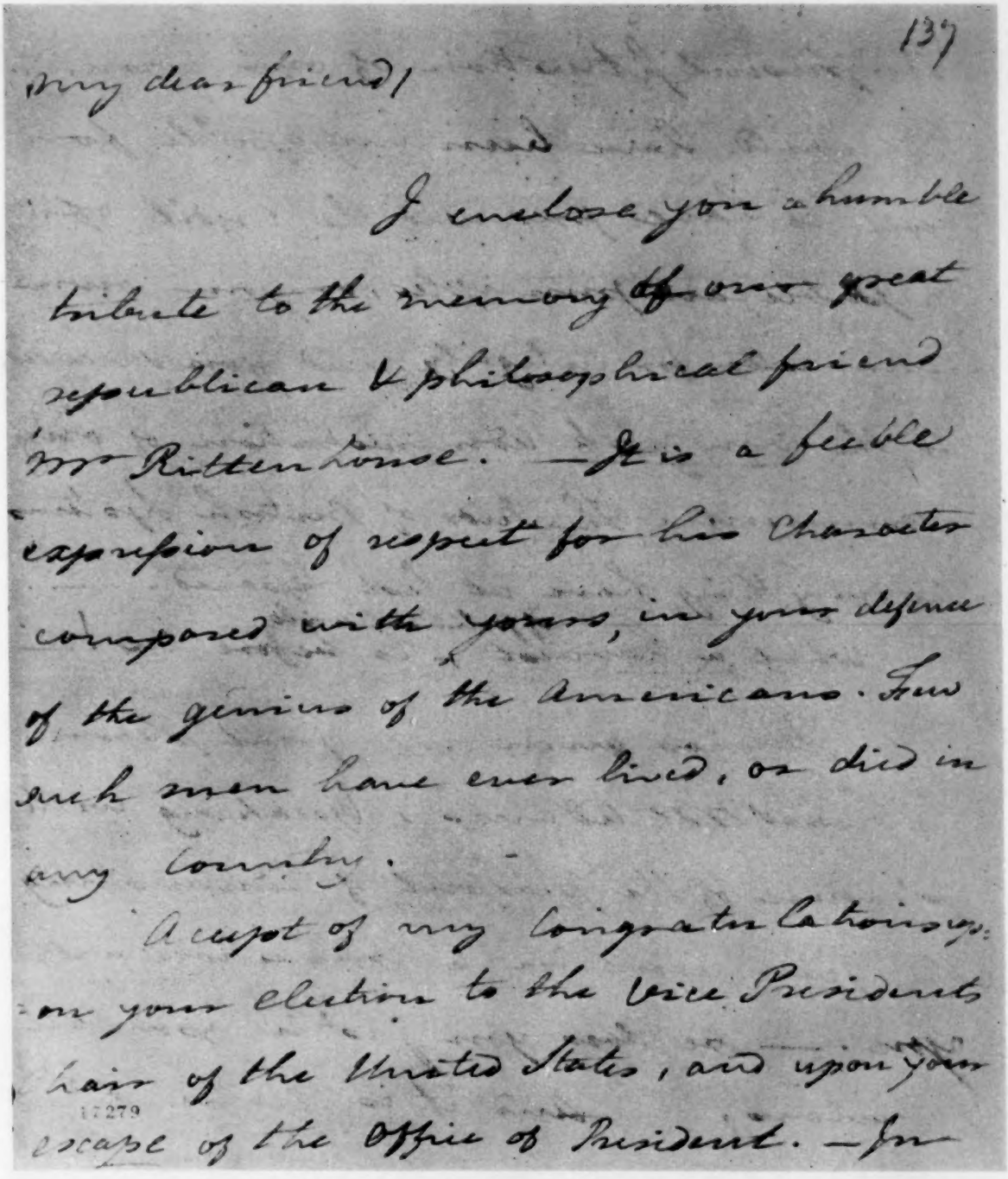
The paper on the Sugar Maple, read in 1791, is a representative effort and reveals its era as well as its author. It took the form of a letter to Secretary of State Thomas Jefferson, who had suggested the subject to Rush.[12] The Iroquois had produced maple sugar; and, as a forest product obtainable without expensive processing, it early attracted the attention of those interested in promoting American natural resources.[13] With the great expansion into the forested lands of the Iroquois after the Revolution, the commercial possibilities of maple sugar were highly appealing. A group of land magnates in central New York State, of whom Judge William Cooper (father of the novelist) is the best remembered, furnished data on production methods and capacity to government officials and merchants in the seaboard cities and met an enthusiastic response.[14] This promotion scheme, which might be called the Great Maple Sugar Boom, had special attractions for the Quaker gentry of Philadelphia. Many of them owned wild lands in the west, and all of them were interested in means to strike at the institution of slavery, upon which West Indies cane-sugar production was grounded. Rush himself was interested for both these reasons and was a principal figure in the Society for Promoting the Manufacture of Sugar from the Sugar Maple Tree, founded in 1789.[15] Besides methods and statistics Rush's essay furnishes many arguments for the use of maple rather than cane sugar. The patriotic motive was so obvious as scarcely to require statement. We have already mentioned the humanitarian argument. There were also hygienic considerations. Rush pronounced maple sugar purer because made in a cool season by clean workers. With respect to the relative strength of the two sugars he cited a tasting experiment conducted by himself, Henry Drinker, Secretary of the Treasury Alexander Hamilton, and several ladies, "who all concurred" in an opinion favoring maple sugar. As a dietitian Rush commended

[12] Rush to Jefferson, Jan. 26, 1792; MS., Princeton Univ. Library.

[13] Hedrick, Ulysses P., *A History of Agriculture in the State of New York*, 35, Albany, N. Y. State Agric. Soc., 1933; Paul Dudley, Account of the Method of Making Sugar from the Juice of the Maple Tree in New England, contributed to the *Transactions* of the Royal Society, 1720, and reprinted in Perry Miller and Thomas H. Johnson, eds., *The Puritans*, 747–748, N. Y., Amer. Book Co., 1938.

[14] See Rush's paper, as reprinted in his *Essays, Literary, Moral & Philosophical*, 275–294; Phila., 1798; also Tench Coxe, *A View of the United States of America . . .*, 78–82, London, 1795.

[15] Rush, Notebooks, vol. 1; MS., Library Co. Phila. The Society dissolved in 1795; see Nathan G. Goodman, *Benjamin Rush, Physician and Citizen, 1746–1813*, 287, Univ. of Penna. Press, 1934.



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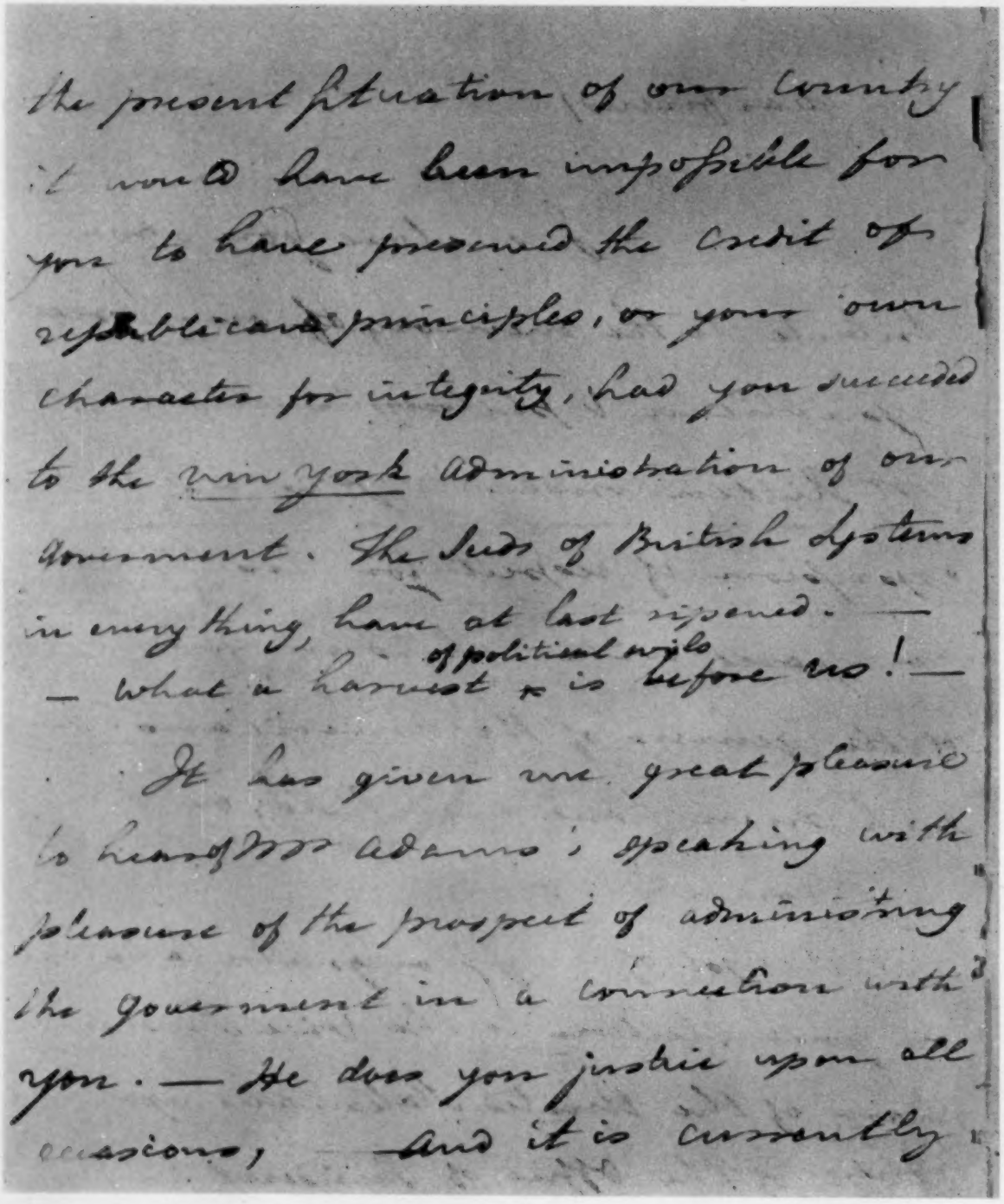
My dear friend!

I enclose you a humble tribute to the memory of our great republican & philosophical friend Mr Rittenhouse. — It is a feeble expression of respect for his character compared with yours, in your defence of the genius of the Americans. Few such men have ever lived, or died in any country.

Accept of my congratulations on your election to the Vice Presidents Chair of the United States, and upon your 17279 escape of the Office of President. — In

FIG. 1. Autograph letter from Rush to Jefferson, January 4, 1797, presenting a copy of Rush's *Eulogium* on David Rittenhouse, late President of the American Philosophical Society, and intimating that Jefferson has been proposed as Rittenhouse's successor. From the original in the Jefferson Papers in the Library of Congress.

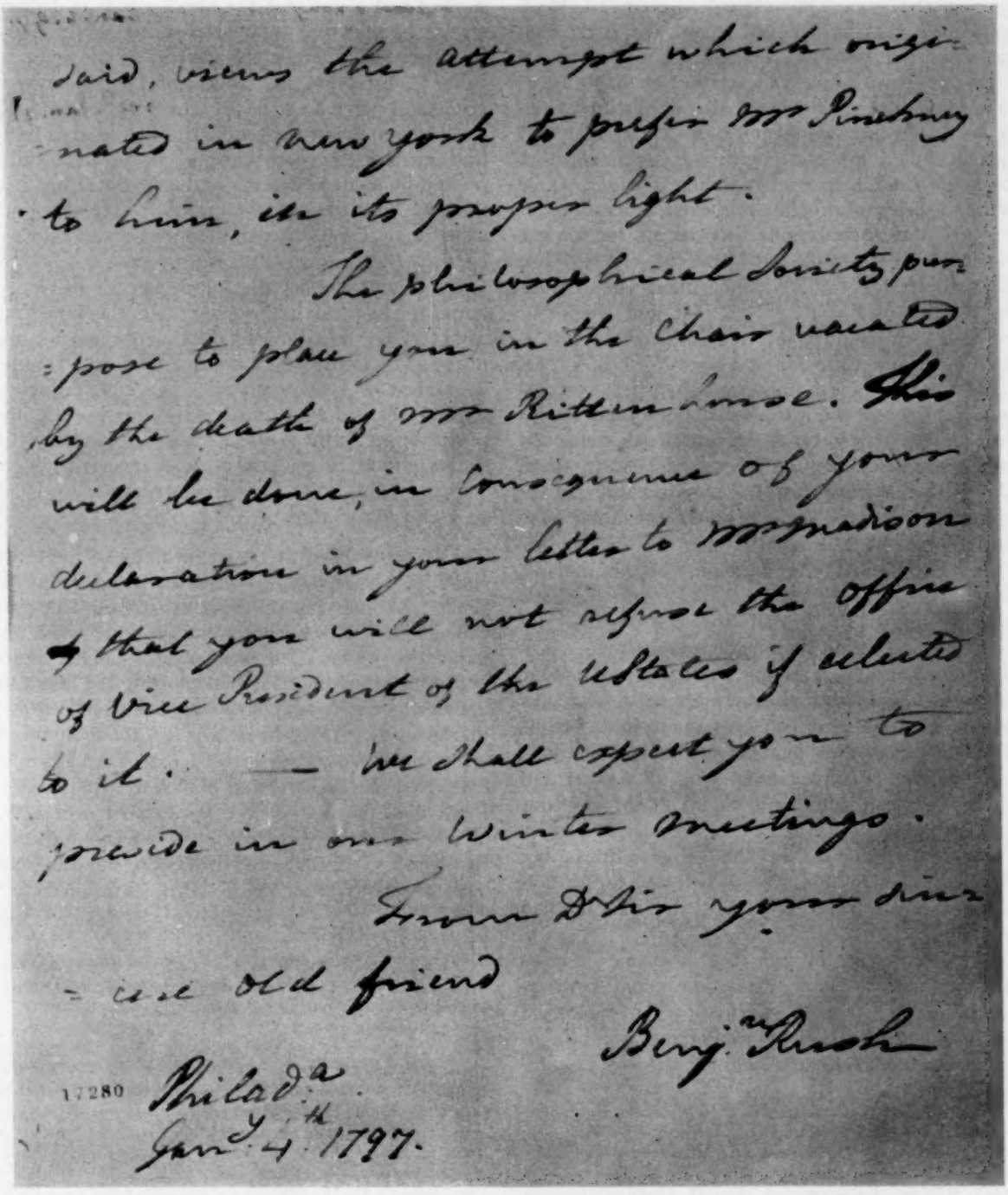
FIG. 1—*Continued*



the present situation of our country it would have been impossible for you to have preserved the credit of republican principles, or your own character for integrity, had you succeded to the new York Administration of our Government. The Seeds of British Systems in every thing, have at last ripened. — — what a harvest of political evils is before us! —

It has given me great pleasure to hear of Mr Adams's speaking with pleasure of the prospect of administring the Government in a connection with you. — He does you justice upon all occasions, — And it is currently

FIG. 1—*Continued*



said, views the attempt which originated in New York to prefer Mr Pinkney to him, in its proper light.

The philosophical society purpose to place you in the chair vacated by the death of Mr Rittenhouse. This will be done, in consequence of your declaration in your letter to Mr Madison that you will not refuse the office of Vice President of the United States if elected to it. — We shall expect you to preside in our winter meetings.

From D[ea]r Sir your sincere old friend

Benj[a] Rush

17280 Philad[a]
Jan[y] 4th 1797.

the plentiful use of sugar, citing the habit of Dr. Franklin of eating blackberry jam to relieve the pain of the stone. Franklin had confided, Rush explained, that he believed it was the sugar that acted as the remedial agent. As a temperance advocate, Rush praised the virtues of maple beer; conceding that spirits could also be distilled from it, he hoped they would not be. No wonder that he concluded his essay with the sentiment that he could "not help contemplating a sugar maple with a species of affection and even veneration." [16]

Rush's most ambitious literary efforts for the Society were his two formal orations, one on "The Natural History of Medicine among the Indians in North-America . . ." (1774), and the other entitled "An Enquiry into the Influence of Physical Causes upon the Moral Faculty" (1786). Of these the first is less important than it is symptomatic. From it we learn less about Indian health and disease—these being subjects Rush continued to inquire about until the end of his life—than about Rush's views on the evolution of human culture. The modish doctrine of the noble savage, though he was familiar with it, was not for him. He admired the stateliness of the Indians' bearing and speech, and he spoke with perhaps some feeling of the inroads that the diseases and vices of civilization had made among them. On the other hand, he does not here appear as a naive disciple of perfectibilitarian progress. Let us admit, he says in effect, that civilization breeds dreadful vices and bafflingly complex diseases, but then let us combat them with all the art and energy we can summon. Some might consider his peroration sentimental, but in it he merely expresses confidence in the opportunities that America, as a middle ground between forest savagery and European effeteness, offers for human happiness.

The oration on the influence of physical causes upon the moral faculty has some claim for consideration as a pioneer statement in psychological science, and has had the respectful attention of historians of American thought.[17] For full analysis the historians must be referred to. The significant step that Rush took in the oration was to announce and argue that the mind, which is demonstrably as sensitive to physical stimuli as the body, is theoretically under the control of medicine as fully as the body is. Much of his evidence is crude and naive, and the argument is studded with apologies to the orthodox.[18] But he declared flatly that mental disorders can be more successfully treated by medical therapy and a healthful regimen than by "lectures upon morality." He therefore called upon his listeners—the members of this Society in 1786—to institute researches into "moral science" and to pool the knowledge of the legislator, the natural philosopher, and the physician in aid of the schoolmaster and clergyman for the purpose of improving morals. The result could be a race of Benezets and a peaceful, crimeless world. This was a little enthusiastic, but the principle set forth in his address is a landmark in the evolution of psychiatry from necromancy to science. This was a signal contribution by Rush to useful knowledge.

As a scientist in the strict meaning of the term, Rush has not been highly regarded by later generations. No one except William Cobbett has ever called him a quack, but, from the time when his magnetic presence as teacher and public figure began to wane in men's memories, the reaction has been steadily against his medical thinking and therapeutics. "We have always thought him," wrote Samuel Jackson in 1861, "most wonderfully entangled in the web of his own sophistry." [19] Rush was the last of the systematists—creators of monistic theories of pathology—whose position just short of the threshold of modern medicine has been so lucidly explained by Professor Shryock.[20]

[16] For the wide circulation of this tract, see the bibliographical appendix to this paper, item no. 13.

[17] See I. W. Riley, *American Philosophy: The Early Schools*, chapter on Rush at p. 421 ff., N. Y., Dodd, Mead, 1907; Paul R. Anderson and Max H. Fisch, *Philosophy in America, from the Puritans to James . . .*, 272 ff., N. Y. and London, Appleton-Century, 1939; Merle Curti, *The Growth of American Thought*, 164, N. Y., Harper, 1943. The oration has been very recently reprinted with an introduction in Joseph L. Blau (ed.), *American Philosophic Addresses, 1700–1900*, 312–343, Columbia Univ. Press, 1946.

[18] E.g., "Let it not be suspected, from any thing that I have delivered, that I suppose the influence of physical causes upon the moral faculty, renders the agency of divine influence unnecessary to our moral happiness. I only maintain, that the operations of the divine government are carried on in the moral, as in the natural world, by the instrumentality of second causes"—*Med. Inq. and Obs.* II: 38, 2nd ed., 1805.

[19] Article on Rush in Samuel D. Gross, ed., *Lives of Eminent American Physicians and Surgeons of the Nineteenth Century*, 64, Phila., 1861.

[20] Shryock, R. H., *The Development of Modern Medicine . . .*, chap. 2–3, N. Y., Knopf, 1947; see the same author's admirable appraisal in Benjamin Rush from the Perspective of the Twentieth Century, *Trans. and Stud. of the College of Physicians of Phila.*, ser. 4, **14**: 113–120, 1946.

In view of the unanimously severe judgment on Rush as a medical scientist, it is but fair to point out that a careful reader will find in Rush's writings much, if widely scattered, evidence of his use of data from the laboratory and dissecting room. A single striking example will be found in a paper he read before the Philosophical Society on a famous cancer cure of the time, in which he reported his exposure of a quack medicine by impeccably scientific methods.[21]

Rush was, moreover, a tireless advocate of experimental science. In his writings on education he pleaded again and again for the introduction of scientific subjects into the curriculum. America being a new country, he reasoned, the kinds of knowledge most needed were those required for the study of our physical environment and the advantageous use of its products; that is, botany, chemistry, mineralogy, and so on, especially in their relations with agriculture, trade, and industry.[22] It was for this reason that Rush opposed with such vehemence the teaching of Latin and Greek through so many years of school. Under the circumstances, he said, it "is to turn our backs upon a gold mine, in order to amuse ourselves catching butterflies." [23] Rush's long and triumphant struggle to procure a first-rate "philosophical apparatus" for his darling college at Carlisle would make an entertaining story in itself. Upon his own students in the medical school he ceaselessly urged the prosecution of scientific studies in varied fields. Such studies, he said, would yield pleasure to physicians as avocations and also, perhaps, discoveries of consequence in the line of their profession. In one lecture, after mentioning American contributions to the materia medica, he declared he had "no doubt but there are many hundred other plants which now exhale invaluable medicinal virtues in the desert air. . . . Who knows but that, at the foot of the Allegheny mountain, there blooms a flower that is an infallible cure for epilepsy?" [24] Rush sent forth from his lecture room hundreds of pupils inspired with a glowing faith in experimental science.

As to method, that is another matter. We know from contemporary observers, from Rush's own writings, and above all from his surviving manuscripts what his methods were. They can best be called cumulative. He noted down a very great deal, if not everything, that he saw, read, heard, and speculated upon. Everyone in the learned world who came to Philadelphia visited Rush; if not voluntarily, then by command invitation. There is a delightful picture of Rush at work gathering data by a young contemporary who was invited to Rush's house one night in 1804 when the explorer, von Humboldt, passed an evening there:

> I cannot forget an evening when the late Dr. Benjamin Rush, then my neighbour, asked me, then quite a young man, to join two or three friends, to meet Von Humboldt and General Miranda at his temperate supper-table. I can never forget the occasion, and I still retain parts of the interesting remarks of Von Humboldt, in his replies to Dr. Rush's queries. The conversation was principally between the two. I was altogether a listener. Dr. Rush's queries generally were directed to points connected with his own profession, the character and cure of diseases among the natives (aboriginals) of certain parts of South America which Humboldt had explored, the differences between the level and mountain ranges, the phenomena of parturition (accouchement), gestation, etc., the general treatment of fevers, wounds, etc., and the peculiarities in physiology and pathology in certain particulars. I recollect also some interesting inquiries into the sources from which Von Humboldt had obtained the best instruments for philosophical experiment or observation on his travels,—thermometers, barometers, meters of every kind, magnifiers, telescopic and microscopic, quadrants, sextants, etc.[25]

Rush's data from all sources went into his notebooks to be levied on for his letters and his lectures and eventually for his formal writings, the long series of "observations" and "inquiries" that vary in length from a few pages to separately printed treatises. From the ill-digested character of some of these productions, it is not unfair to say that the inquiring philosopher sometimes threw together "An Account of" or "An Inquiry into" this or that phenomenon as soon as he had enough notes on the subject to give the needed bulk.

A case in point is Rush's tract on the skin color of Negroes, read to the Philosophical Society in 1797 and printed in the fourth volume of the *Transactions* (1799). His hypothesis is that the pigmentation of Negroes' skin is actually owing to

[21] An Account of the late Dr. Hugh Martin's Cancer Powder, with Brief Observations on Cancers, *Trans. Amer. Philos. Soc.*, o.s. 2: 212–217, 1786.

[22] *Essays*, 17–18, 47–48, 79–80.

[23] *Essays*, 39.

[24] *Med. Inq. and Obs.* I: 407, 2nd ed., 1805.

[25] Horace Binney to Francis Lieber, Jan. 26, 1860; Charles C. Binney, *The Life of Horace Binney. With Selections from His Letters*, 46, Phila. and London, Lippincott, 1903.

a sort of leprosy in reverse. The evidence he adduces is an astounding mass of travelers' tales, museum curios, and crude experiments reported at second hand. The "reflections" that follow his "proofs" are equally astounding. The moral lesson is of course that "all claims of superiority of the whites over the blacks, on account of their color, are founded alike in ignorance and inhumanity. If the color of the negroes be the effect of a disease, instead of inviting us to tyrannise over them, it should entitle them to a double portion of humanity." This is humane enough, but it therefore follows that all intermingling of racial stocks should be avoided—in order to prevent the spread of leprosy! The duty of science and humanity is to unite in finding a cure for the disease. Rush recommends bleeding, aided by applications of "oxygenated muriatic acid" and the juice of unripe peaches.

In brief, Rush was often, as Dr. Johnson said of Pope as a metaphysician, "in haste to teach what he had not learned." His mind was fertile and inexhaustibly suggestive; he offered a hundred useful ideas, from short haircuts for soldiers for the improvement of military hygiene [26] to a humane stoolpan for use in insane asylums.[27] But he was so utterly uncritical in his use of evidence and in verifying his conclusions that his contributions to pathology are almost negligible. His significant contributions were to the marginal areas of medical science: to psychiatry, veterinarianism, municipal and military sanitation, and above all to medical education. Most of these were new and unclaimed fields, in which thinking, writing, and right feeling had to precede correct clinical techniques, and Rush's services as a propagandist were indispensable to their development.

Both by precept and example Rush helped materially to raise the standard of medical training in the United States. This is a subject for an essay in itself and cannot be examined here. Instead, I should like to emphasize that his program of medical education was by no means limited to the training of competent professionals. If asked to state the most important contribution Rush made to the betterment of human life, I would point out for consideration his lifelong crusade for the popularizing of medical knowledge in all its aspects and especially in those which concern all men all the time—the elementary rules of good health. To put these within everyone's reach was the first article in Rush's creed as practitioner, teacher, and writer. Little attention has been given to this phase of Rush's work, but it was a persistent and highly constructive phase of his many-sided career. His first book had a quaint title: *Sermons to Young Gentlemen upon Temperance and Exercise.*[28] Yet its advice on temperance in eating and drinking, on exercise and sports, and on the folly of dosing oneself with nostrums is as sound now as when it was written. Furthermore, the advice was put in plain language, for it was Rush's early conviction, stated in the dedication of this book, that "Physic will never suffer by undeceiving the common people; but, on the contrary, like the Reformed Religion, it will become illustrious by stripping it of its pageantry." [29] To Rush there was no reason why the rules of health, hygiene, and diet should not become a regular part of "academical education in all our seminaries of learning." No reason, that is, except conservative educational tradition. "We teach [our children] what was done two thousand years ago, and conceal from them what is doing every day." The preparation of nourishing food, the symptoms of oncoming disease and what to do about them, the principles of what we now call first aid, are subjects, he insisted, not above the capacities of those who can master Latin grammar and the propositions of Euclid.[30] In a republic the physician should be an educator rather than the practitioner of an occult art. So Rush interpreted his own role. And if he oversimplified

[26] Letter to Anthony Wayne, Sept. 29, 1776; MS., Hist. Soc. Penna., Wayne Papers.

[27] Letter to the Managers of the Pennsylvania Hospital, Oct. 10, 1810; Thomas G. Morton and Frank Woodbury, *The History of the Pennsylvania Hospital, 1751–1895*, 150, rev. ed., Phila., 1897.

[28] Philadelphia, 1772; it was reissued in London the following year under the more captivating title of *Sermons to the Rich and Studious, on Temperance and Exercise.*

[29] For this reason Rush urged, with eventual success, that medical theses should be written in English, rather than Latin; see *Sixteen Introductory Lectures*, 142. At the turn of the century a choice between Latin and English was permitted to candidates presenting theses, with obvious consequences. For earlier criticism of doctors' keeping trade secrets by using Latin, see Shryock, *Development of Modern Medicine*, 52.

[30] See *Sixteen Introductory Lectures*, 154–155. For first aid specifically, see the "Directions" for recovering supposedly drowned persons and other victims of accidents, drawn up by Rush and widely circulated as broadsides and in magazines and almanacs by the Humane Society of Philadelphia. A letter from Rush to the Humane Society of Massachusetts, March 9, 1793 (MS., Library Co. Phila., Rush MSS.), gives some account of the Philadelphia Society's work and principles.

a science that is still confronted by major mysteries, he anticipated at many points the programs in health education and domestic science that we take for granted in our schools today. One cannot read without delight and surprise Rush's little *Syllabus of Lectures, Containing the Application of the Principles of Natural Philosophy, and Chemistry, to Domestic and Culinary Purposes.* Delivered at Andrew Brown's Young Ladies' Academy during 1787, the lectures covered the whole range of domestic matters to which scientific knowledge could be applied: the location, materials, heating, and sanitary arrangements of a house; the materials of dress; the care and treatment of plate, dishes, furniture, bedding, books, and the like; the preparing and preserving of foods and drinks of all sorts. Attention was also given to smoky chimneys, to clocks and thermometers, to soap and candles, to pens, ink, and paper, and even to "the means of preserving Female Beauty"—a subject on which one would especially like to have heard Rush's pronouncements. A copy of the *Syllabus* among Rush's papers in the Library Company contains additions in the author's hand, evidently for a later course. Among them are headings for instruction on gardening, the care of horses and cows, and remedying "trifling disorders" in which doctors do not need to be consulted. Rush overlooked little. His determination to be useful in his generation and to the democratic America he envisioned can scarcely be better illustrated than in these lectures to Schoolmaster Brown's young ladies. One might look far, indeed, to find a better application to practice of the ideals which the American Philosophical Society was founded to promote.

CHECKIST OF RUSH'S WRITINGS FOR THE AMERICAN PHILOSOPHICAL SOCIETY [31]

1. An Account of the Effects of the Strammonium or Thorn-Apple.

Read Nov. 2, 1770. Published in *Trans. Amer. Philos. Soc.*, o.s., **1**: 318–322, 1771.

2. An Enquiry into the Methods of Preventing the Painful and Fatal Effects of Cold upon the Human Body.

Read Jan. 3, 1772. Published anonymously in the *Columbian Mag.* **1**: 427–431, May 1787.

3. Enquiry into the cause of Sleep & Dreams.

Offered to the Society and referred to the Medical Committee, July 18, 1773. Never published?

4. Experiments and Observations on the Mineral Waters of Philadelphia, Abington, and Bristol, in the Province of Pennsylvania. Read June 18, 1773, before the American Philosophical Society. . . . James Humphreys, Junior, 1773.

According to the Minutes, this paper was read *July* 18, 1773.

Hildeburn 2926, Sabin 74220, Evans 12995.

For the absurd affair of the supposedly medicinal Philadelphia waters, see F. H. Shelton, Springs and Spas of Old-Time Philadelphia, *Penna. Mag. Hist. Biog.* **47**: 196–237, 1923.

5. An Enquiry into the Cause with an Acct. of the Efficacy of Liquid Laudanum in the Disorder bro't on by drinking cold Water.

Read Nov. 19, 1773. Published under the title "An Account of the disorder occasioned by drinking cold water in warm weather, and the method of curing it" in Rush's *Medical Inquiries and Observations* [I]: 129–132, 1789, and in later editions of this work. The substance of the paper was used in the directions posted by the Humane Society at public pumps in Philadelphia; see the *Amer. Museum* **2**: 160–164, Aug. 1787.

6. An Oration, Delivered February 4, 1774, before the American Philosophical Society, held at Philadelphia. Containing, An Enquiry into the Natural History of Medicine among the Indians in North-America, and A comparative View of their Diseases and Remedies, with those of civilized Nations. . . . Joseph Crukshank, [1774].

Hildeburn 3096, Sabin 74237, Evans 13592.

Reprinted in Rush's *Medical Inquiries and Observations* [I]: 9–56, 1789, and in later editions.

Translated as "Untersuchung der Arzneykunde unter den Indiern in Nordamerika, und Vergleichung ihrer Krankheiten und Heilungsmittel mit denen, die bey gesitteten Völkern gewönlich sind," in *Hannoverisches Magazin . . . vom Jahre 1776*, Jahrgang **14**: col. 1457–1470, and continuations, Hanover, 1777.

7. An Enquiry into the Cause of the Increase of Bilious and Intermitting Fevers in Pennsylvania, with Hints for preventing them.

Read Dec. 16, 1785. Published in *Trans. Amer. Philos. Soc.*, o.s., **2**: 206–212, 1786.

8. An Account of the late Dr. Hugh Martin's Cancer Powder, with brief Observations on Cancers.

[31] Dates of reading are taken from the MS. Minutes of the Society or from the published papers themselves. The place of publication, if not otherwise given, is Philadelphia. Bibliographical references to Evans, Sabin, Hildeburn, and Meynen are given when an article has been separately published.

Read Feb. 3, 1786. Published in *Trans. Amer. Philos. Soc.*, o.s., **2**: 212–217, 1786; also in the *Amer. Museum* **1**: 29–32, Jan. 1787; and, with the title "An Account of the external Use of Arsenic in the Cure of Cancers," in Rush's *Medical Inquiries and Observations* [I]: 163–168, 1789, and in later editions.

9. An Oration, Delivered before the American Philosophical Society, Held in Philadelphia on the 27th of February, 1786; Containing An Enquiry into the Influence of Physical Causes upon the Moral Faculty. . . . Charles Cist, 1786.

Sabin 74235, Evans 19972.

A second edition was issued the same year (Evans 19973), also a London edition, published by C. Dilly (Sabin 74236). The paper was reprinted in Rush's *Medical Inquiries and Observations* II: 1–56, 1793, and in later editions. It has been frequently reprinted, wholly or partly, down to 1946.

10. Observations on the Cause and Cure of the Tetanus.

Read March 17, 1786. Published in *Trans. Amer. Philos. Soc.*, o.s., **2**: 225–231, 1786, and in the *Amer. Museum* **2**: 461–464, Nov. 1787. The paper had, however, been *first* read (Feb. 10, 1786) to the Medical Society of London, in the form of a letter from Rush to Dr. John Coakley Lettsom dated July 16, 1785; it was later published in the Society's *Memoirs* **1**: 65–76, 1787. (I am indebted to Mr. W. B. McDaniel, 2d, Librarian of the College of Physicians of Philadelphia, for this information.) Reprinted in Rush's *Medical Inquiries and Observations* [I]: 169–176, 1789, and, much revised, in later editions.

11. Thoughts on Common Sense.

Read Feb. 18, 1791. Published anonymously in the *Universal Asylum and Columbian Mag.* **6**: 211–214, April 1791. Reprinted in Rush's *Essays*, 249–256, 1798.

A note at the head of the text in the *Universal Asylum* states that, though the paper was read to the Philosophical Society, "the subject of it being wholly metaphysical, it was conceived to be foreign to those branches of science, which have hitherto engaged the attention of the Society. It was, therefore, withdrawn by the author."

12. Inquiries and Observations upon Old Age.

Read May 6, 1791.

This is probably an early version of "An Account of the State of the Body and Mind in Old Age . . . ," in Rush's *Medical Inquiries and Observations* II: 293–321 (1793), which also appeared in later editions and in Sir John Sinclair's *Code of Health and Longevity* IV: 514–531, Edinburgh, 1807.

13. An Account of the Sugar Maple-Tree, of the United States, and of the Methods of obtaining Sugar from it, Together with Observations upon the Advantages both public and private of this Sugar. In a letter to Thomas Jefferson. . . . Read in the Philosophical Society, on the 19, of August, 1791, and extracted from the third volume of their Transactions now in the Press. . . . R. Aitken & Son, 1792.

Sabin 74201, Evans 24761.

London edition, J. Phillips, 1792; also reprinted in the *Universal Asylum and Columbian Mag.* **8**: 166–175, March 1792; *Trans. Amer. Philos. Soc.*, o.s., **3**: 64–81, 1793; Rush's *Essays*, 275–294, 1798. In the Society's archives there is an interesting MS. letter from Rush to John Vaughan, Nov. 25, 1791, relative to the publication of this tract. Rush says that "the impatience of the gentlemen interested in the sugar lands will render it difficult to detain it much longer from the public eye."

Translated as "Nachricht von dem Zucker-Ahorn in dem Nordamericanischen Freystaaten, und von der Art und Weise, Zucker aus demselben zu erhalten . . . ," *Neues Forst-Archiv* **3**: 49–88, Ulm, 1797.

14. An Eulogium, Intended to Perpetuate the Memory of David Rittenhouse, Late President of the American Philosophical Society, Delivered before the Society in the First Presbyterian Church, in High-street, Philadelphia, on the 17th Dec. 1796. . . . J. Ormrod, [1796].

Sabin 74219, Evans 31143, Meynen 7258.

Reprinted in Rush's *Essays*, 343–378, 1798.

15. Observations intended to favour a supposition that the Black Color (as it is called) of the Negroes is derived from the Leprosy.

Read July 14, 1797. Published in the *Trans. Amer. Philos. Soc.*, o.s., **4**: 289–297, 1799.

CULTURAL RELATIONS AND INTERNATIONAL UNDERSTANDING

HAYWARD KENISTON

Dean, College of Literature, Science and the Arts, University of Michigan

(*Read November 20, 1947*)

So many of the men who have served the Department of State in the last five years for a brief tour of duty as cultural attaché have recorded their impressions of his functions that it is perhaps presumptuous to attempt a new appraisal. But the present organization of cultural relations in the Department of State is so unsatisfactory and their aims are so distorted that it is important to reexamine the purpose of a cultural relations program and its role as an instrument of international understanding.

When the United States in 1938 belatedly recognized the importance of cultural relations in foreign affairs by the creation of a Division of Cultural Relations, the men who formulated the plan had a clear vision of its aims: their purpose was to encourage and strengthen cultural relations and intellectual cooperation between the United States and other countries. With inadequate financial support and an inexperienced staff, the fledgling Division slowly laid the foundations for the new edifice. When the war came, three years later, the Department reaffirmed its faith in the original purpose, "the development of that reciprocal understanding essential to harmonious political relationships and to the most effective cooperation in defense of common interests."

The story of cultural relations in the war years is one of steady growth of the program in foreign lands and of administrative confusion in Washington. Again and again the Division of Cultural Relations was reorganized and reallocated; it received new names and new structural places; at times it operated without a chief. Its field of operations was overlaid by the creation of the Office of the Coordinator of Inter-American Affairs. But happily a few men survived the constant changes in the Department and built an operation in the field that firmly established the main lines of cultural communication.

The war had barely ended when President Truman abolished a number of war agencies, such as the Office of Inter-American Affairs and the Office of War Information, and assigned their activities to the State Department. At the same time, the Department created a new "Office of International Information and Cultural Affairs (OIC)" to carry on the work of these agencies and that of the former Division of Cultural Relations.

The very name of the new Office is an indication of a new orientation of Departmental policy in the field of cultural relations. And this is abundantly clear from the statement of the responsibilities of the Office:

> The promotion among foreign peoples of a better understanding of the aims, policies, and institutions of the United States.
>
> The coordination of policy and action for programs of the United States in the field of international information and cultural affairs.
>
> The dissemination abroad of information about the United States through all appropriate media.
>
> The promotion of freedom of information among peoples.
>
> The furtherance of the international exchange of persons, knowledge, and skills.
>
> The integration of the over-all United States foreign policy of the programs and activities of other federal agencies, involving international interchange of persons, knowledge, and skills.

Bluntly stated, this means that the OIC is primarily an instrument of American propaganda, aimed at winning support for the "American way of life" and designed to back up our international political policy. The appointment of a successful advertising executive as Assistant Secretary in charge of the Office further emphasized its new function. OIC was to "sell" the United States to the world. If the field of cultural relations was given a place in the program, it was more of a stepchild than ever. Its high purpose of mutual understanding and cooperation in a world of nations was wellnigh forgotten.

Anyone who is familiar with the psychology of other peoples is aware of the dangers of official foreign propaganda. Everywhere men have learned to suspect the radio, the press, even the movies when used as instruments of a foreign government. They may be fooled by the propaganda of their own government, but they discount and resent the efforts of foreigners. Our own attitude toward Nazi or Fascist or Soviet propaganda,

even toward the British Broadcasting Corporation, is ample evidence of how people react to such nationalistic programs. We are on the wrong track if we think that propaganda leads to understanding and peace.

Even if we accept that free access to information is a goal to be encouraged, information is not an end in itself; it is a means. It is equally essential to political, economic, and cultural understanding and cooperation. To tag cultural relations as an appendage onto an Office of Information reveals a complete misconception of their mutual relations.

For cultural relations should be one of the three major divisions of our foreign office. To the original political division, concerned with the relations of our government with other governments, there has already been added an economic division, dealing with the promotion of our trade with foreign lands. It is time that we recognized the necessity of creating a coordinate cultural division, charged with the duty of promoting mutual understanding between men of good will in every land through the medium of common ideas and common ideals. Here, more than in any other area, there is hope for the future, because here, and only here, may we deal, not with the defense of national interests nor the fierce competition for profit, but with the promotion of a common cause through cooperation. And this divisional organization within the Department should be reflected by the appointment of a Counsellor for Cultural Affairs in each of our foreign missions, coordinate with the Counsellor for Economic Affairs and the Counsellor of Embassy in the political field, and responsible to the Chief of Mission in the field of cultural contacts for duties comparable to theirs.

That field has so often been described by the Department and by men who have participated in the program that I need not undertake a detailed analysis of its scope. The main types of activity are four:

I. The development of personal interchange (civic leaders, professional men, artists, students).

II. The development of institutional interchange (learned and professional societies, educational institutions, libraries, museums, social welfare agencies, religious organizations).

III. The development of the media of cultural communication (books, magazines, microfilm, music, the press, radio, the movies, lectures, concerts, art exhibits, etc.).

IV. The development of sources of information (libraries, cultural institutes, information centers, etc.).

It is clear that the Department of State and its cultural attachés cannot assume the responsibility of conducting all these activities. From the first the Division of Cultural Relations has accepted the principle that its function was to coordinate and encourage the activities of the many private organizations already working in the field. It is my personal conviction that they should more and more rely upon these private entities to operate in clearly defined areas, creating new agencies, where the need exists, and subsidizing their operations with government funds.

Already the Department is utilizing the Institute of International Education as its agent in the field of student exchange. The American Library Association was at one time its agent in the distribution of books. It might well go farther along this path. Why should it not create an organization called "International Publications, Inc." to promote the exchange of books, to facilitate translations, on a reciprocal basis, in order that we may better understand the ideas of other lands, as well as that they may understand ours?

One of the most controversial problems in the field of cultural relations has been the role of radio, and I do not need to review the debates which have occupied the attention of Washington and the country at large. But I must record my own belief that government-sponsored broadcasting from Washington is little likely to promote mutual understanding; it may even have the effect of arousing distrust in foreign lands. The very fact that our news agencies and our broadcasting systems are free organizations and not subservient to government control gives to their communications an integrity and an authority which no government office can hope to achieve.

On the other hand, the radio provides an incomparable instrument for cultural purposes, if it is organized to that end and not for the purposes of propaganda. To attain this purpose it must be conducted locally in each of the countries, in the language of the country and through local stations. Here again I would set up an international agency, subsidized by the Government, with the task of coordinating our efforts, providing materials of cultural significance, and distributing its materials concerning the United States to operating agencies in other capitals, at the same time

that it distributed cultural materials concerning other countries to American broadcasting stations. The essence of a cultural program is reciprocity; it is a two-way track, not a single track.

With an adequate organization in the Department of State, the effectiveness of the program of cultural relations will depend on its field representatives, the so-called "cultural attachés," assigned to our foreign missions. The present field organization, in which the cultural attaché is a minor officer under the "Public Affairs Officer," is absurd; it is putting the cart before the horse. It carries into the field the distortion of the Department's structure. For the cultural attaché should, I repeat, hold rank as a Counsellor for Cultural Affairs, directly responsible to the Ambassador or Minister. Under his direction, in the larger missions, there might well be a Press Officer, a Science Officer, a Labor Officer, a Welfare Officer, or an Art Officer. He should be responsible for analyzing, reporting, and interpreting to the Department and to the American public the complex cultural pattern which explains a nation's political and economic actions. At the same time, he must interpret to the nationals of the country to which he is assigned the institutions and ideals which give to the United States its peculiar quality.

What manner of man can fulfill these conditions? This, too, is a problem that has often been discussed in print. Perhaps the simplest answer would be to say that in the experience of the last five years the men who have had the greatest success as cultural officers have been men who were specialists in the area to which they were assigned, who spoke the language fluently and with cultivated distinction, and who had a consuming passion to promote mutual understanding. They have been writers, artists, scholars, librarians, and archaeologists; they have been men of liberal minds. Because they spoke with the authority of their personal prestige, because they served no ulterior purpose, political or commercial, they have had an unusual success in strengthening the cultural ties between the peoples they touched and the American people.

During the war it was possible to enlist the services of men of competence as a kind of patriotic duty. Most of them served for a period of only two years. Should we continue to recruit cultural attachés as temporary officers or should we train foreign service officers for this special assignment? We must, I think, do both things. In any large embassy, the routine duties of the cultural relations section are so numerous that a considerable staff is necessary. To meet this situation there is only one reasonable solution: to train foreign service officers as specialists in cultural affairs for service in a specific region. After a trial period to permit an evaluation of an officer's interests and aptitudes, he should be assigned to special training. If he is to be a cultural relations specialist, he should be sent to a graduate school for advanced work in the particular area to which he is to be assigned—Latin America, the Scandinavian countries, the Far East—for he must speak the language and be recognized as an expert, if not an authority, in the culture of the country in which he serves.

The Department will also need the services of men who have won distinction as intellectual leaders and who may, in truth, be cultural ambassadors to foreign lands. In times past men of this type have often been named by the President as his political ambassadors or ministers. It would be wiser to appoint them for a term of five years as cultural attachés. How much happier William Dodd would have been in Germany as a cultural officer! He might even have been more effective! There must be many American leaders, at the height of their intellectual power, who would count it an honor to serve the high cause of international understanding under the aegis of the Department of State. And as they returned to their normal tasks, they would enlarge and enrich the understanding of our own people because of this opportunity for service.

As the range of cultural contacts widens, there is reason to believe that there will be need for a large number of appointments at our foreign missions of men to conduct special studies and special programs. Some of them will be recruited from the federal departments which are grouped in the Interdepartmental Committee on Scientific and Cultural Cooperation. But the majority should be drawn from the younger staff of American universities. The instructor in education who is assigned to a foreign post for a two-year tour of duty to study the educational system of the country will not only offer valuable service to the cultural relation section of the mission through his personal contacts with educators; he will bring back to his institution new insights into the culture of the country he has studied to the benefit of his colleagues and his students.

In all that I have said, I have stressed the necessity of reciprocal relations as the heart of our cultural program. There are many ways of life beside the American way; we have as much to learn from other peoples as they have to learn from us. This process of learning is an individual matter. It comes from personal contacts with men and women who represent another culture, from the experience of their ideas and their society. That is why the post of cultural attaché attains such significance: he becomes the symbol of our faith in individual human understanding as the only foundation of an ultimate understanding among nations.

We cannot expect that in a few years or a generation men will everywhere be seized with a passion for human brotherhood. But we may be sure that, at their best, the divergent human cultures will tend to converge in a common aspiration for such ideals as beauty, truth, justice, freedom. The first step toward such a fusion of ideals lies in the path of cultural relations. For here, men of different language and background already possess the bases of common interest; they speak a common professional idiom; they are aware of the benefits of cooperation. As the number of these contacts and associations increases, the circle of their influence will widen. Since they are the leaders in the life of their nation, their attitudes and their teaching will reach deeper and deeper into the thought and action of their fellow citizens. Only when we have achieved this community of understanding among men of good will, here and in other lands, will peace become a reality.

READING AND VISUAL FATIGUE

LEONARD CARMICHAEL

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(*Read November 20, 1947*)

A KODACHROME motion-picture film was presented to show a method developed by the speaker and his associates to make possible the study of the movements of the eyes during long periods of reading.

After preliminary experiments, Professor W. F. Dearborn, other collaborators, and the speaker undertook an experimental study of visual fatigue in reading, using the techniques shown in the film. This study was financed by the Committee on Scientific Aids to Learning of the National Research Council. The conditions and results of the experiment were briefly as follows:

Twenty college and twenty high school subjects read for each of two experimental periods. Each period was six hours long. Half the college and half the high school students read from the ordinary printed pages of two books. The other half read from microfilm projections of the same books in a commercial microfilm projection device. Each book was read for six hours. One of the books was Adam Smith's *Wealth of Nations,* Vol. II. The other was Richard Blackmore's *Lorna Doone.* The first of these books was considered to be "dull" by certain of the subjects; the second was frequently described as "interesting." The level of illumination on the pages of the book during reading was approximately 16 footcandles. The level of illumination of the background of the microfilm page was approximately 15 footcandles. Temperature, humidity, and extraneous sounds were also controlled in the electrically shielded chamber in which the subject sat during the reading periods.

Continuous recordings were made of every eye movement occurring during each of the two six-hour reading periods for all forty subjects. It is a tribute to the amplifiers and ink-writing oscillograph used that during the almost 500 hours of use no difficulties arose in the apparatus such as to require a repetition of any record. These records, totalling approximately fifteen miles in length, were later edited and individual measures on the records were tabulated. A number of these tabulated measures were then studied. The measures studied included in unit time periods: (1) number of blinks; (2) number of fixation pauses; (3) number of fixations per line; (4) variation in number of fixations (sigma score); (5) number of lines read; (6) number of regressive movements; (7) number of regressions per line.

Besides these measures taken from the record of the electro-oculogram, other evidence was collected from all subjects. This evidence included measurement of: (1) visual acuity; (2) stereoscopic acuity. These measurements were made both before and after each six-hour reading period. Before reading the subjects were also asked to complete a questionnaire which was intended to secure from them their subjective impressions concerning their ability to read and their own evaluation of their general reading habits. At the end of each six-hour experimental period questions were also asked about the subjective feelings experienced during the reading period.

In addition to emphasis on data of these two types, much emphasis was also given to the measuement of the subject's comprehension of what he had read. At the end of each six-hour reading period each subject took an objective examination intended to measure his broad understanding of the book that he had just been reading. Detailed examinations were also given during each reading period. These tests were made up of at least one multiple-choice question on every page of both books. These objective tests were printed in type like the books. These question pages were inserted every twenty-five pages. The subject used a pencil in marking his answers to the multiple-choice items on each such test. The subject signalled when he began each test by a series of rapid blinks and also signalled at the end of the test in the same manner. During the test all eye movements were recorded. The eyes were continuously active when the tests were taken. The tests were not rest periods.

Statistical evaluation was made of the results of these tests of comprehension and also made of all other measures. No statistically significant work decrement or fatigue change was demonstrated in any objective measure studied in any subject or group of subjects under any of the conditions of the experiment.

The conclusion is therefore presented that, at least for the typical groups studied, continuous reading for six hours produced no measurable fatigue changes in eye performance or in comprehension. This conclusion holds alike for the "dull" and for the "interesting" book. The one exception to this generalization is that a number of subjects reported subjective feelings of fatigue as the experiment progressed. These subjective feelings of fatigue, eyestrain, and "wishing to stop" were not correlated with any loss of measurable efficiency in reading or any change in the comprehension of the material read. In this connection it may be pointed out that the subjects were highly motivated as a result of at least the following three factors: (1) financial rewards; (2) desire to cooperate in a scientific experiment; (3) desire to do well in the examinations used in the experiment. In a preliminary experiment in which these motivating factors were not at such a high level, signs of a work decrement appeared in some subjects during a four-hour reading period.

Some implications of the present study seem to be: (1) When positively motivated so that they tried to read carefully and for good comprehension normal subjects could read for six hours without producing measurable fatigue. The experimenters also gained no information concerning any so-called hidden cost to the organism in the experiments. (2) These conclusions apply to microfilm reading as well as to the direct reading of printed books.

Two of many possible programs of action following the study may be suggested: (1) Longer assignments may well be given in much educational work than are usually assigned at present. (2) The training of students to disregard transitory subjective feelings of fatigue in reading may be recommended.

More details concerning these experiments are given in Carmichael, Leonard, and Walter F. Dearborn, *Reading and Visual Fatigue,* pp. xiv + 483, Boston, Houghton Mifflin Co., 1947.

SCHOLARSHIP AND THE INTELLIGENCE PROBLEM

WILLIAM L. LANGER

Coolidge Professor of History, Harvard University

(*Read November 20, 1947*)

In the long-drawn discussions over the recent "merger" of the armed services little attention was given to one item which seems to me to be of great—not to say vital—importance. This item, which was incorporated in the final legislation, involved the reorganization of the intelligence services of the government. Previously existing agency services have now been subordinated to a new Central Intelligence Agency, which in turn is placed under the new Council for National Defense. Henceforth—in theory at least—all foreign intelligence activity which has a bearing on the national security will be directed and coordinated by the new agency, serving not only the highest echelons of the government, but the President himself.

I do not propose on this occasion to analyze the organization or functioning of this new service. Suffice it to say that it reflects appreciation of a need that was keenly felt during the recent war and that has now been recognized as essential for the formulation and implementation of American foreign and military policy. Things being what they are in the world today, it would be simply laboring the obvious to stress the constant and urgent need for reliable, up-to-date information on foreign powers, with particular reference to their capabilities and intentions. My purpose is merely to examine one aspect of the subject—one which I think should be of interest to members of this Society.

The general problem of intelligence involves two quite distinct activities. One is the gathering of materials and information abroad. To many people this suggests at once the glamorous if somewhat dishonorable and un-American work of secret intelligence and espionage, which is indeed part of the job and one that has become particularly important in this age of secret weapons and intense scientific competition, to say nothing of the foreign police systems that have closed huge areas to ordinary observation and study. Nonetheless, the popular notion is quite mistaken. Most of the information required concerning other nations can still be obtained by very ordinary, unspectacular methods. Trained collectors under proper guidance and with adequate funds can procure probably 85 to 90 per cent of the needed materials and data.

Far less dramatic but in my opinion much more important is the other aspect of the intelligence problem, namely, the analysis of information and its processing into meaningful reports. The idea has certainly been prevalent, at least in government circles, that anyone with a modicum of common sense could put two and two together and come up with the correct answer. Even though in 1939 our intelligence collecting system was very inadequate, it was infinitely superior to our arrangements for analysis. In certain restricted fields, such as fiscal matters and problems of foreign trade, excellent research was being done in the Treasury, Federal Reserve Board, and Department of Commerce. These agencies had highly trained staffs and were fully aware of the fact that such technical matters as international finance or taxation required specialized study. But in the political field little was done. From time to time some academically-minded official in the Department of State might essay an historical survey or a systematic analysis, but such cases were exceptional. For the most part the Department operated on the strength of personal knowledge and accumulated experience. Basic study and long-range planning were all but unknown.

The Army and Navy were almost as casual in their treatment of the problem. They had intelligence branches, but these were staffed by officers mostly without special qualifications, often by men regarded as unsuitable for field or sea command, who, by the mere issuance of orders, supposedly could be transformed over night into "experts." Under the circumstances it would have been little short of a miracle if high-grade intelligence reports had emerged. Actually the estimates and conclusions of the Service intelligence staffs were notoriously inadequate and sometimes mistaken to a dangerous degree.

During the war a real effort was made to correct this sad situation. When General William J. Donovan in August 1941 organized what later became the Office of Strategic Services, his chief

aim was to bring into government service scholars who, in addition to their specialized knowledge of foreign countries, were trained in particular disciplines and thoroughly grounded in the methods of assembling, selecting, evaluating, and presenting evidence. Later the OSS expanded its activities into other fields and many of you, no doubt, have read thrilling accounts of the adventures and exploits of its secret agents and operatives in even the most remote parts of the world. But throughout the whole war period the original idea was unobtrusively developed. By 1945 the Research and Analysis Branch comprised a staff of some five hundred professional people working in Washington, to say nothing of a couple of hundred others working at various stations abroad and scattered all the way from London to Chungking.

This unpublicized research staff consisted of scholars drawn from all the social science fields—economists, political scientists, historians, geographers, psychologists, archaeologists, and even philologists. The great objective was to get these specialists to work together, to pool their knowledge of the materials and literature and to focus their various techniques on specific problems in the hope of coming up with the best-informed, most comprehensive, and most critical estimates of particular situations.

The idea was excellent, but the operation was difficult. We ran into obstacles internally and externally. Not only did we discover how little competence this country could furnish in certain fields, but we were shocked—some of us at least—to find how narrow much of our specialization had become and how difficult it was to get people from the various disciplines to work together. For example, it turned out not only that we had very few people competent in the Russian, Far Eastern, and Near Eastern fields, but also that few if any of our American economists or psychologists had concerned themselves with foreign problems. In like manner there was, especially at the outset, much suspicion of the procedures and conclusions arrived at by unfamiliar techniques. To mention only one instance, in the Russian field the economists were sure that they alone could deal adequately with economic problems, while the Russian specialists pointed out, with considerable cogency and much persistence, that the economists not only knew nothing of the Russian materials, but were abysmally ignorant of the peculiar Russian conditions.

I will not dwell at length on these difficulties. Gradually they were overcome and in the end I believe we went a long way towards our original objective. Many excellent reports were produced in greatly diverse fields and I am certainly not overstating the case when I say that new standards and indeed new techniques were established for many types of work.

Externally the arrival of the professors was greeted in characteristic Washington fashion, with some derision and more suspicion, not to say outright and avowed hostility. I recall that at first we were solemnly warned never to use the word "strategy," so as not to evoke too violent antagonism from the Services. This did not prevent our emergence, after a year, as the Office of Strategic Services. Then we were told to avoid scrupulously any reference to "policy," so as not to arouse the susceptibilities of the State Department. Yet at the end of the war the entire research branch was transferred to the Department on the plea that it was essential for the study and formulation of policy.

In a word, the strain and stress of war hastened the process of education. Originally we had to grope our way and apply ourselves to those things that seemed important and within our competence. Often we did not learn until too late of real needs, and often we labored hard only to find that our effort was simply duplication. Many of our most solid and valuable reports, I am sure, never reached those people who could have profited most from them. But all this is part of the general Washington experience and I will not dwell on it. What seems to me to be of permanent importance is that the OSS staff demonstrated the value and need of specialized research. Towards the end of the war recognition of our work was so general that we were hopelessly pressed. Even in purely operational fields such as bomb targets and determination of enemy losses our help was regarded as indispensable. But, above all, in the study of the capabilities and intentions of foreign powers I think we went far beyond anything previously known in Washington or previously attempted anywhere else, even in Germany. On these problems we could bring our full competence to bear, analyzing all possible aspects of the problem and integrating the results into a comprehensive report.

The most convincing proof that we had made our mark was the decision made to maintain the research branch when the rest of the OSS was disbanded in 1945. At that time there was much

heated debate regarding the allocation of the organization and this, in my opinion, is a really very difficult organizational problem, which I will not attempt to discuss here. The essential thing is that, under the State Department, the activity has continued uninterruptedly, and that there is little likelihood that in the future it will be seriously curtailed or jeopardized.

What we have, then, in the government is something like a huge social science research institute devoted to the exploration of certain types of problems bearing directly on the national security. Whether it remains in the State Department or is ultimately transferred to the new Central Intelligence Agency is no doubt important, but not decisive. The principle has been established and the need recognized. I cannot conceive of the government ever being willing to dispense with it, and I am confident that, for the future, the work of the organization will serve as an incentive to closer coordination in the social sciences. Already the regional studies programs in many institutions reflect its influence on the universities.

But this new departure, like most others, has its shady side. The question of personnel is and undoubtedly will remain for a long time the controlling factor in determining success or failure. During wartime the staff was built up by draining the universities, but that could never be anything more than an emergency procedure. It stands to reason that, with the end of the conflict, many members of the staff and more particularly the senior, directing members, should have returned to their habitual callings—after all, the needs of the universities after demobilization were just about as great and as urgent as those of the government during hostilities. The result has been that the intelligence research staff has been decapitated and generally depleted, with only faint prospect of improvement in the immediate future. The plain fact of the matter is that we have far from enough trained people in these fields to staff both the universities and the government.

This is obviously a question that should be considered in connection with the government program for training and research. In the social science fields the results are of course less concrete and spectacular than in the fields of science and invention. Furthermore, the exact preparation is difficult to define and organize. But it is, I am convinced, very necessary that encouragement be given and that concerted efforts should be made to enable promising students to get training in the less familiar fields, as well as to study and live abroad. The regional programs in the universities represent hopeful beginnings, but the load is heavy and the road is long. My hope is that, as appreciation of the problem spreads, something larger and more systematic will be undertaken and that, ultimately, it will be realized that the country has a real stake in the type of study that is clearly essential for any nation which, whether it likes it or not, is called upon to play a major part in world affairs.

MAN'S GREATEST ILLUSION

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(*Read November 20, 1947*)

MACAULAY in his essay on Francis Bacon spoke of "illusions to which the whole human race is subject, and which experience and reflection can only partially remove." He had been studying Bacon's *Novum Organum* and, like others before him and since, was deeply impressed by it, so deeply as to say that "no book ever made so great a revolution in the mode of thinking—overthrew so many prejudices—introduced so many new opinions." His attention had no doubt been caught by Bacon's famous exposition of "idols" (*idola* in Bacon's Latin, from the Greek εἴδωλα), those erroneous beliefs and conceptions which obstructed the advancement of knowledge. The more general of such untrue notions, those grounded in human nature and common to the whole human species, Bacon called idols of the tribe, or race, and it was of these that he was thinking when he likened the human mind to a false mirror, which distorts the nature of objects by mingling its own nature with it. He denied that man is the measure of things, and he asserted that nature can be commanded only if she is obeyed. Nevertheless Bacon did not make explicit mention of the most prolific of all of man's illusions, the source of a host of impediments to understanding —the illusion of anthropocentrism and anthropomorphism. During almost the entire course of man's existence, ever since he has been capable of thinking about his relation to the external, he has taken it for granted that he occupied, quite literally, a central position in the physical universe and that non-human objects and beings possessed attributes similar to his own.

Anthropology tells us that primitive man assumed the world around him to be full of spirits; and during that long stage of human culture characterized by this belief in spirits, or animism, any object might be regarded as possessed of life, soul, will, purpose, and other human attributes. The object might be inanimate or animate, to use categories that were not yet sharply distinguished. It might be a heavenly body, the sea, a river, a volcano; or it might be an animal or a tree. Deism developed out of animism. The conception of spirits as immanent in objects is much older than the conception of man-like deities who rule objects. In the words of Sir James Frazer in *The Golden Bough:*

> The process of thought which leads to the change from the one mode of conception to the other is . . . the gradual investment of the immanent spirits with more and more of the attributes of humanity. As men emerge from savagery, the tendency to humanise their divinities gains strength; and the more human these become, the wider is the breach which severs them from the natural objects of which they were at first merely the animating spirits or souls. But in the progress upwards from savagery men of the same generation do not march abreast; and though the new anthropomorphic gods may satisfy the religious wants of the more developed intelligences, the backward members of the community will cling by preference to the old animistic notions.

Animism, indeed, is still a going concern in primitive communities in various parts of the world, and survivals of animism are still all around us. Young children are always animistic, as observant parents well know; and even civilized adults—we ourselves, no less—become animistic under the influence of strong emotions. "A melancholy bird?" asks Coleridge in his poem, "The Nightingale":

> A melancholy bird? Oh! idle thought!
> In nature there is nothing melancholy.
> But some night-wandering man, whose heart was pierced
> With the remembrance of a grievous wrong,
> Or slow distemper, or neglected love,
> (And so, poor wretch! fill'd all things with himself,
> And made all gentle sounds tell back the tale
> Of his own sorrow), he, and such as he,
> First named these notes a melancholy strain.

Coleridge was describing poetically an instance of what Ruskin later expounded at length and labeled "the pathetic fallacy." In the discussion of this subject in his *Modern Painters* Ruskin quotes these lines from *Alton Locke,*

> They rowed her in across the rolling foam—
> The cruel, crawling foam,

and says in comment:

The foam is not cruel, neither does it crawl. The state of mind which attributes to it these characters of a living creature is one in which the reason is unhinged by grief. All violent feelings have the same effect. They produce in us a falseness in all our impressions of external things, which I would generally characterize as the "pathetic fallacy."

From animism as the primitive cosmic philosophy, however, our ancestors did emerge quite a while ago, and it is only traces and vestigial remnants of animism that are to be found among civilized peoples today. Anthropomorphism, on the other hand, still holds us in its grip. It is basic in orthodox religions; and it is implied in humanistic attitudes and cults in which man is viewed as the culmination of a cosmic purpose, for purpose is a human attribute. Philologists might take exception to the statement that anthropomorphism is embedded in those languages which, like French, possess no neuter gender and ascribe sex to all objects, even to all ideas. But the proposition is at least arguable.

There is in all of us a kind of subconscious vanity, though a better name could perhaps be found for it. We cannot bear to think that we are cosmically unimportant. We can, of course, no longer believe, as our forebears believed up to some ten generations ago, that we are, literally, at the center of the physical universe. Nevertheless it is still possible for us to believe that we are at the apex of creation. In what we know about the universe, to be sure, there is no good reason whatever for believing this; but, as Bacon was so well aware and as modern psychology so strongly emphasizes, men usually have little difficulty in believing what they wish to believe. There are some modest individuals in the human race, and we should rejoice in their presence among us; the race as a whole, however, resembles Captain Cuttle in Dickens's *Dombey and Son*—Captain Cuttle, who used to walk down the street winking at his own sagacity. The burden of proof, I suggest, should rest upon those who ascribe to us—to you and to me—a position of unique distinction and eminence in the universe. The fact that we are predisposed to believe what is flattering to our vanity is the best of reasons for questioning our belief. "To have doubted one's own first principles," in the words of Justice Holmes, "is the mark of a civilized man."

Anthropocentrism in the literal sense depended, of course, upon the geocentric cosmology which originated with primitive man and received its most refined formulation at the hands of Claudius Ptolemy and his school of astronomy. It perished with the overthrow of that cosmology in the astronomical revolution with which the names of Copernicus and Galileo are associated. As a description of the universe as a whole, the sun-center theory of Copernicus may not seem like much of an improvement on the earth-center theory of Ptolemy. Both are about equally remote from present-day cosmological conceptions. Still the Copernican revolution *did* depose man from his self-arrogated station at the center of everything. And the subsequent amazing development of astronomy has taken place with no greater consideration for his egoism. I have read predictions to the effect that we would cease to be civilized—would return to savagery—if we ceased to believe in our own ultimate importance. I believe that these are false prophecies. We did not cease to be civilized when the astronomical revolution displaced us from our preferential position at the center of the cosmos—quite the contrary.

To our ancestors, who lived with dignity and decorum on a stationary earth at the center of a tidy and well-regulated universe, with all the celestial bodies respectfully revolving around them in perfect circles, the situation in which we find ourselves would seem intolerably degraded. Here we are, the erstwhile lords of creation, parasites of a minor planet of a commonplace and wholly undistinguished star, which is but one of some billions that form a galaxy which itself has uncountable fellows—transported in a bewildering maze of motions at astonishing velocities, with the rotation of the earth on its axis, with the revolution of the earth around the sun, with the sun in its galaxy, and with the galaxy through space toward—who knows where? The earth is subject to half a dozen major motions, and there are lesser ones. I have heard Harlow Shapley say (in private conversation, but I think he would not object to being quoted) that he had examined photographs that show some galaxies distant from us approximately one billion (1,000,000,000) light years, and that within the portion of space lying within this radius (i.e., a spherical piece of space with the earth as its center and a radius of a billion light years) there are probably about a billion galaxies comparable in magnitude to our own Milky Way System and averaging more than ten billion stars apiece. That is to say, ten billion billion stars in what is at most only a small fraction of that total space which Einstein has taught us to

conceive of as finite but boundless. And how many of these stars may be the parents of planetary systems more or less like our own Solar System I leave to the conjecturings of professional cosmologists. This is the universe we have to reckon with, and in it a man must be completely obsessed with a sense of the cosmic importance of himself and his fellow human beings, must be a victim of the merest wishful thinking, if he does not come to question the arrogant assumption that the species to which he belongs represents evolution's highest product. The fact that the development of astronomy has had so little effect upon our estimate of our cosmic significance is striking evidence of the strength of human vanity and of our almost total immersion in immediacies of one kind or another—which is closely related to our vanity.

There is time to speak of only one of the great philosophers who have rejected anthropomorphic conceptions of Deity: the saintly and lovable Baruch Spinoza. He was regarded by his seventeenth-century contemporaries—Catholics, Protestants, and Jews—and for a long time after his day as a monster of impiety; and to those who can think of God only in anthropomorphic terms Spinoza's religious ideas must seem indistinguishable from atheism, in spite of his explicit repudiation of the charge when it was brought against him. In Part I of his *Ethics,* entitled "Concerning God," Spinoza denies that even the highest attributes of man are attributes of God.

> I know that there are many who think that they can show that supreme intellect and free will do appertain to God's nature; for they say they know of nothing more perfect which they can attribute to God than that which is the highest perfection in ourselves . . . [But] if intellect and will appertain to the eternal essence of God, we must take these words in some significations quite different from those they usually bear. For [the] intellect and will which should constitute the essence of God would perforce be as far apart as the poles from the human intellect and will, in fact, would have nothing in common with them but the name; there would be about as much correspondence between the two as there is between the Dog, the heavenly Constellation, and a dog, an animal that barks.

Probably no one has understood better than Spinoza how deeply ingrained anthropomorphism is in the human mind. In replying to a puzzled correspondent he wrote:

> . . . when you say that if I deny that the operations of seeing, hearing, attending, wishing, &c., can be ascribed to God, or that they exist in Him in any eminent fashion, you do not know what sort of God mine is; I suspect that you believe there is no greater perfection than such as can be explained by the aforesaid attributes. I am not astonished; for I believe that if a triangle could speak, it would say, in like manner, that God is eminently triangular, while a circle would say that the divine nature is eminently circular. Thus each would ascribe to God its own attributes. . . .

Like Bacon, Spinoza viewed the human mind as a distorting medium. Everybody mistakes for external things the forms of his imagination, he declared, adding that "all the explanations commonly given of nature are mere modes of imagining, and do not indicate the true nature of anything, but only the constitution of the imagination." What Spinoza taught, however, was doctrine that few men have been willing to accept.

Illusions of grandeur may take many forms; for example, individual, national, racial, and human racial. The only remedy for them—unless indeed they rise to psychopathic dimensions, in which case other forms of therapy may be "indicated"—is the spirit of humility, that "highest virtue, mother of them all," as Tennyson called it. Unfortunately, however, humility is one of those virtues to which we pay lip service. We give it an airing, perhaps, on Sundays but a complete rest on weekdays.

I wish to urge with all seriousness and emphasis that the pursuit of this virtue of humility ought to be a major objective of education, though this is not the occasion for an exhibition of plans and blueprints. Morally wise men, whatever their fields of endeavor, have always recognized the saving graces of humility and the indispensable role that humility plays in the higher life of man. Let me summon a few witnesses.

The first was a devoted searcher after truth in the realm of physical science, the late Max Planck, author of the Quantum Theory and known to us all by reputation at least. In a work entitled (in its English translation) *The Philosophy of Physics,* a book intended for the layman, he says:

> Every individual science sets about its task by the explicit renunciation of the egocentric and anthropocentric standpoint. In the earlier stages of human thought . . . primitive man made himself and his own interests the center of his system of reasoning. Confronted with the powers of nature around him, he thought that they were animated beings like himself and he divided them into two classes, the one friendly and the other inimical. He divided the

plant world into the categories of poisonous and non-poisonous. He divided the animal world into the categories of dangerous and harmless. As long as he remained bound within the limits of this method of treating his environment, it was impossible for him to make any approach toward real scientific knowledge. His first advance in this knowledge was accomplished only after he had taken leave of his own immediate interests and banished them from his thought. At a later stage he succeeded in abandoning the idea that the planet whereon he lives is the central point of the universe. Then he took up the more modest position of keeping as far as possible in the background, so as not to intrude his own idiosyncrasies and personal ideas between himself and his observations of natural phenomena. It was only at this stage that the outer world of nature began to unveil its mystery to him, and at the same time to furnish him with means which he was able to press into his own service and which he could never have discovered if he had continued looking for them with the candlelight of his own egocentric interests. The progress of science is an excellent illustration of the truth of the paradox that man must lose his soul before he can find it. The forces of nature, such as electricity for instance, were not discovered by men who started out with the set purpose of adapting them for utilitarian purposes. Scientific discovery and scientific knowledge have been achieved only by those who have gone in pursuit of it without any practical purpose whatsoever in view.

My second witness is that courageous philosopher, the late Morris R. Cohen, who, among other shining merits, never hesitated to stand up and be counted when he found himself in dissent from prevailing tendencies of thought. My quotations are all taken from the recently published collection of his posthumous papers called *The Faith of a Liberal:*

> . . . we need resignation to learn to live in a world that is not formed just for our own comfort. . . .
>
> . . . because the practical is important and must not be neglected, it does not follow that the theoretical is of no inherent importance, or that it can be justified only to the extent that it ministers to the practical—that pure science, for instance, has no justification as an activity in itself, but has value only to the extent that it finds application in technology and the like. I regard the latter view as intellectually and morally vicious. . . .
>
> Too much absorption with human problems is intellectually narrowing. . . . It is a great help . . . to see that our present life is but an episode in the history of mankind, and the latter but an insignificant incident in cosmic history. Such wider vision not only diminishes the exaggerated importance which we attach to most of our practical concerns, but is, as an exercise of supreme intellectual energy, a good in itself if anything is good . . . it impoverishes philosophy to minimize those cosmic interests which have always constituted its life-blood. And our view of the human scene becomes narrow, unillumined, and passionate if we do not rise above its immediate urgency and see it in its cosmic roots and backgrounds. . . .
>
> The faith of the liberal, as of the scientist, grows out of a deep humility which recognizes the limitations of mortal finitude and acknowledges the impossibility of any individual's attaining correct answers to all the problems that he faces. But this humility is combined with a hope that, through rational communication and collaboration among individuals, a living body of common thought may be created which will more adequately answer the problems of an age or society than can any individual, whether he be a scientist or a dictator. . . .

Before presenting my third and last witness I should like to say a few words of introduction. Nobody who has paid any attention to recent tendencies in historiography, especially in this country, would be likely to question the proposition that one of its outstanding characteristics is present-mindedness. By this I mean the point of view of those who believe that the only value of the study of the past is to explain the present. Now if the historian accepts this point of view, he will, of course, omit or play down those past events and developments that do not seem to him to account for the present, no matter how important they may have seemed to men at the time, and, conversely, he will throw his spotlights on those that do appear to him to explain the present, no matter how unimportant they may have seemed at the time. Present-mindedness is an essential ingredient of what has been called "the new history"; but actually there is really nothing new about it. On the contrary, it is extremely old, in fact primitive. It causes those who yield to its blandishments to see the past through the distorting medium created by their own present-day standards and presuppositions. Seeking to explain the present in the light of the past, they end by viewing the past, unconsciously or consciously, in the light of the present. They do not perceive that it is bad logic to infer that the past explains the present, even though this be true, from the fact that a historical account seems to explain some present situation *when it has been deliberately constructed for this purpose.* Present-mindedness bears the same relationship to man's attitude toward the past that anthropomorphism bears to

man's attitude toward the universe around him. It is, and always has been, the great distorter of the past, the great source of anachronism, the great foe of historical-mindedness. As a phenomenon of our time it is bound up with that cult of the present to which our sense of self-importance, rationalized by the dogma of evolutionary progress in human affairs, has given rise.

It is gratifying to our self-esteem to look upon ourselves as the heirs of all the ages, but that does not justify us in supposing that the ages existed for the heirs. Historical occurrences—what men have done and thought and felt—had a validity of their own. They did not happen in order to be mere antecedents; they did not happen merely to lead up to us. We are not final in time any more than we are central in space. It has been said that our earth and its inhabitants are but a bit of star gone wrong. It would be more sensible to think so than to mistake ourselves for that "one far-off divine event, to which the whole creation moves."

I now summon my last witness, a historian who thought deeply about the nature and processes of history, my revered teacher, William Archibald Dunning. As President of the American Historical Association, he delivered, some thirty-five years ago, a remarkable address on "Truth in History." Disturbed by the dominant cult of the timely, Dunning declared that a spirit of temporal humility was the crying need in the study of history:

> Our pride in the attainments of our own day distorts all our judgments of the past. In vain the master-mind of a distant generation rears with matchless ingenuity a system of institutions based on the teachings of Moses or of Numa. We follow out languidly the story of his system, no matter how precisely it fitted the demands of the time. At only one point will our interest revive, when the master-mind, by some chance, hit upon a notion that has acceptance and vogue in our own day. Here we center our attention and appreciation, and in our history of the affair make the central feature, not the ingenious adaptation of the system to contemporaneous needs and environment, but the accidental fact that there was in the situation something that anticipated the thought or achievement of the wonderful twentieth century. . . . The realities of the past will never be scientifically apprehended so long as the student of history stands contemplating in a stupor of admiration the reversals of ancient beliefs effected in our own age. Contempt for those who lacked our light is the worst of equipments for understanding their deeds.

I said a few minutes ago that illusions of grandeur take a number of forms. To these another must be added, that which exalts our own age at the expense of all past ages. The cure for this present-mindedness is that form of humility known as historical-mindedness.

STREPTOMYCIN IN THE TREATMENT OF INFECTIONS

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(*Read November 20, 1947*)

BEFORE the days of modern therapeutics, the practitioner of medicine often wondered how much good he was really doing. When the founder of this distinguished and learned Society, Benjamin Franklin, was in London, his physician was that great humanitarian and philanthropist, John Fothergill, a Quaker, a great friend of the Colonies and of Philadelphia in particular. On one occasion Franklin wrote Fothergill a letter in a bantering style which ran as follows:

> Do you please yourself with the fancy that you are doing good? You are mistaken. Half the lives you save are not worth saving, as being useless, and almost the other half ought not to be saved, as being mischievous. Does your conscience never hint to you the impiety of being in constant warfare against the plans of Providence? Disease was intended as the punishment of intemperance, sloth and other vices; and the example of that punishment was intended to promote and strengthen the opposite virtues. But here you step in officiously with your art, disappoint those wise intentions of Nature, and make men safe in their excesses!

All of us who study the diseases of man fully appreciate that Nature is mainly responsible for many cures. At the present time we are in a better position to assist Nature in bringing about cures than at any other period in the past.

Today, I propose telling you about some of the results that have flowed from the use of streptomycin, and to say something about how streptomycin may step in and assist Nature in the control of infections.

The sucessful use of antibacterial agents derived from microbes marks the beginning of a new period in medical therapeutics. The idea of using one bacterium or its products to combat another began with the classical and world famous experiments on anthrax by Pasteur just seventy years ago. In 1886 Robert Koch demonstrated conclusively that the *Bacillus anthracis* was the cause of anthrax. This was the first disease of man or animals shown to be the result of infection by a specific microorganism. Soon after Koch reported his discovery, a controversy arose over the significance of the anthrax bacillus because Paul Bert announced that he had been able to destroy the organism in a drop of blood by compressed oxygen and then inoculate an animal with what remained, reproduce the disease and cause the death of the animal without any trace of the bacterium. He concluded that the bacteria were neither the cause nor the necessary effect of anthrax, which must be due to a virus.

At this point Pasteur took an active part in the conflict. He grew the anthrax bacillus in artificial media for 40 generations and then reproduced the disease in rabbits and guinea pigs, thus smashing the virus theory. To settle objections that had been made by Jaillard and Leplat, who had caused death of animals by the inoculation of blood from cases of anthrax, without inducing growth of anthrax bacilli in the blood of the experimental animals, Pasteur went to Chartres. There he found the carcass of a sheep dead sixteen hours, that of a horse dead about a day, and that of a cow dead two or three days. The blood of the sheep contained only anthrax bacilli and induced anthrax in guinea pigs. Putrefactive organisms but no anthrax bacilli were found in the blood of the horse and the cow. The blood of these animals, when inoculated into guinea pigs, caused death from sepsis but not from anthrax. The experiments of Jaillard and Leplat were thus explained. The putrefactive organisms had killed the aerobic anthrax bacillus. By cultural methods Pasteur succeeded in separating the aerobic anthrax bacillus from the anaerobic putrefactive organisms responsible for the deaths from sepsis. Further, he was able to show that when other organisms were mixed with anthrax bacilli and injected into animals, the anthrax bacilli were frequently eliminated and the animal did not die of anthrax. Thus we have the first example of bacteriotherapy in animals.

Most of you know that streptomycin was described by Professor Waksman and his colleagues of Rutgers University in January 1944. It is an antibacterial substance that is derived from the products of the metabolism of *Streptomyces*

griseus, following its growth in a suitable medium. The original strain was isolated from the throat of a chicken, but other strains may be found in heavily manured soil. It is now known that there are two forms of streptomycin called Streptomycin A and Streptomycin B. Both of these chemical substances are biologically active, but Streptomycin A is four to five times as active as Streptomycin B. They are strong organic bases which combine readily with acids to form salts; that is, the hydrochloride, the sulfate, or calcium chloride double salts. These salts are readily soluble in water and when injected into the muscles they are rapidly absorbed and slowly excreted in the urine and bile. They are not absorbed from the gastro-intestinal tract when they are taken by mouth so that treatment must be given parenterally.

Streptomycin inhibits the growth of many micro-organisms. Gram negative bacilli are more sensitive than the gram positive bacteria. Of great interest, of course, is its bacteriostatic action against the tubercle bacillus.

While streptomycin is relatively non-toxic, certain side effects may occur when the dose is large and the duration of treatment is prolonged beyond two weeks. The most disturbing side effect is vertigo or dizziness that may come on with great suddenness in about 5 per cent of patients and persist for several weeks to several months. In most cases the symptom is transitory.

TUBERCULOSIS

The disease that has attracted the widest attention with respect to streptomycin treatment is tuberculosis, which continues to be one of the major problems in infectious diseases. It is world-wide in distribution and in many countries it is the commonest cause of death. In the past forty years great strides have been made in reducing the incidence and hence the death rate from this disease. In fact, the death rate from tuberculosis is lower in the United States than in any other country in the world. At the beginning of this century tuberculosis was the commonest cause of death in all decades of life. Since then the death rates have gradually declined so that tuberculosis now stands seventh in the causes of death in our country, and the annual death rates have fallen from 240 per 100,000 to less than 50 per 100,000 in forty-seven years. If this decline continues the disease is well on its way toward becoming a minor cause of death.

I hasten to add, however, that if this goal is to be achieved, we must continue to focus our attention on prospective gains, both preventive and curative. We must not lose sight of the fact that tuberculosis is still an exceedingly important health problem. It continues to be the leading cause of death in early adult life and it is an important cause of orphanhood and of disrupted families. Ten years ago Drs. Dublin and Lotka of the Metropolitan Life Insurance Company stated that "the time is now ripe for a final and intensified drive which will lead to a suppression of the disease." The discovery of streptomycin has stimulated the drive to further gains. Everyone is anxious to know what streptomycin has done for patients with tuberculosis and what might be anticipated from its widespread use in patients with the disease. Disraeli once said that "Time was the Great Physician," and Osler often remarked that "Time in divided doses" was important in therapeutics. There is no doubt that in the assessment of streptomycin in tuberculosis, time is a most important factor. One cannot make a final assessment at present, but some statements are permitted that mark its present position.

It is the only antibiotic or chemical agent that can be given to man that influences the clinical course of tuberculosis in a favorable sense. It is relatively non-toxic, since the therapeutic dose is less than the toxic dose and, as information accumulates concerning time-dose relationships, it becomes increasingly clear that better results are being obtained with smaller doses, and with fewer side reactions.

CONSTITUTIONAL SYMPTOMS

Following treatment with streptomycin there is often a remarkable and often dramatic change in the constitutional symptoms and signs of infection. The fever decreases, the appetite improves, the patients gain weight, the cough decreases, the amount of sputum diminishes and in at least 50 per cent of patients with pulmonary tuberculosis the sputum becomes free of bacilli during treatment. The incidence of blood spitting decreases in a striking manner. In pulmonary tuberculosis the most striking subjective and objective signs of improvement occur in patients with acute exudative lesions and the improvement in the constitutional signs of the disease precedes the improvement as disclosed by the Roentgen ray.

In many forms of extra-pulmonary tuberculosis the results of streptomycin treatment have been very striking indeed. This includes generalized

tuberculosis, tuberculosis of the meninges, bones, skin and subcutaneous tissue, larynx, trachea and bronchi, intestinal tract, and renal tract.

The results in far advanced pulmonary tuberculosis and in silicotuberculosis have been disappointing.

The conservative attitude that has been adopted so far is that patients who have a good outlook with the usual forms of sanatorium and medical care should not be treated with streptomycin. This opinion was developed as a result of two factors: (1) the incidence of vertigo is moderately high, and (2) the appearance of tubercle bacilli that are resistant to the action of streptomycin following treatment is frequent. With the lower dosage schedules, the incidence of vertigo has been reduced and it is of short duration in most patients. The significance of streptomycin-resistant tubercle bacilli is not clear with respect to virulence and invasiveness. That is to say, it is not known whether streptomycin-resistant organisms that appear during treatment are more or less virulent than the strains that were present prior to treatment. In some instances the tuberculous process spreads after organisms become resistant; in others continued regression of the lesions occurs. In any event, the results of streptomycin treatment in tuberculosis are extremely encouraging and justify a widespread use of this important agent.

TULAREMIA

In the autumn of 1910 Dr. R. H. Pearse, a practitioner of medicine in Brigham City, Utah, described a disease that he observed in six of his patients following the bite of the large black and yellow horse or deer fly (*Chysops discalis*). These were among the first clinical cases of what is now recognized as tularemia to be described in the United States, but it was not until later that these cases of so-called "deer fly" fever were known to be caused by *B. tularense*. In 1912 McCoy and Chapin of the U. S. Public Health Service isolated from rodents in California a bacillus which was causing a plague-like disease. Since the infected ground squirrels were found in Tulare County, California, the organism was named *Bacterium tularense*.

Within two years of this discovery by McCoy and Chapin, the first human cases of tularemia to receive bacteriologic confirmation came from Cincinnati, Ohio. The clinical cases were reported by ophthalmologists since the patients had conjunctivitis with satellite adenopathy. Wherry and Lamb isolated the organisms from the patients and from rabbits in southern Indiana. Since that time, through the efforts of Francis of the U. S. Public Health Service and many others, tularemia has become established as a specific bacterial disease in man. The animal reservoirs of the disease are numerous and include wild rabbits (hares), cotton tail and jack rabbits, ticks and pheasants. The common mode of infection is from handling or coming in contact with infected animals, ingesting infected food or being bitten by an insect that carries the organism from animal to man.

In general, tularemia is a disease of the rural population and attacks persons who work in the fields, men, women, or children. The fatality rate is approximately 6 per cent, although it is much higher in the forms of the disease that resemble typhoid fever and in those accompanied by pneumonitis. Even in patients who finally recover, it is a disabling illness, which overtakes the farmer in the busy season of midsummer, or the hunter in the autumn, causing two or three months of sickness.

Until streptomycin was developed, there was no satisfactory form of treatment. Serum therapy was helpful in some cases but the results were not dramatic. With the use of streptomycin, the outlook improved immeasurably. Now the disease is shortened in its course, the number of relapses is reduced and the fatality rate decreased. All these effects are conclusive. The temperature returns to normal promptly, the initial lesion heals, and the enlarged lymph nodes return to their normal size more rapidly than has ever been observed with any previous form of treatment. These results can be obtained with the use of as little as 0.5 to 1.0 gram a day for five to seven days. In fact, it can be said that streptomycin is practically specific for the treatment of tularemia and has completely changed the course of the disease and its outlook.

BRUCELLOSIS

An extremely important infection in man is brucellosis. Here again the reservoir of infection is in animals (cows, hogs, goats, sheep, horses, dogs, cats, elk, and buffalo). The disease is transmitted to man through contact with infected animals or infected meat from these animals. That is one of the reasons that the disease is commonest in farmers, veterinary surgeons, and slaughter house workers. Others acquire the disease from

the ingestion of milk or cheese that is infected with the organism.

This disease is of great economic importance to farmers and animal breeders, since it causes a loss of large numbers of calves and pigs and reduces the milk production in cows. In man the disease causes great disability, protracted illness, and occasionally death.

Streptomycin is active against the various strains of Brucella in artificial media, and it is effective in eliminating organisms from the organs of infected guinea pigs when the time-dose relationship is properly adjusted. It can also increase the survival rate in the treated infected chick embryo.

In the treatment of human brucellosis with streptomycin the results have been irregular and on the whole disappointing. It will be admitted at once that the assessment of any therapeutic agent in this disease is difficult because of the great variation in the course of the disease. However, it can be said that streptomycin alone will often clear the circulating blood of organisms, at least temporarily, and the febrile course is shortened in some when the treatment is started within the first three weeks of fever. It is also reported that the convalescent period is somewhat shortened.

More recently, Spink has demonstrated that the combined use of streptomycin and sulfadiazine in *Brucella abortus* infections is far superior to the use of either one of these agents alone. His dosage schedule has been two grams of streptomycin for one week and four grams of sulfadiazine for four weeks.

Additional studies of this disease are urgently needed, since a satisfactory agent for use in all cases has not been discovered.

H. INFLUENZAE MENINGITIS

There are four common causes of meningitis—the meningococcus, the tubercle bacillus, the pneumococcus, and the influenza bacillus. Before the days of chemotherapy and specific serum treatment, the fatality rate in influenzal meningitis was approximately 99 per cent. With the introduction of streptomycin, the fatality rate is now less than 10 per cent. This is a great achievement.

URINARY TRACT INFECTIONS

An extremely common group of infections occurring at all ages and in both sexes are those that involve the kidneys and bladder. Pyelonephritis of infancy, pyelonephritis associated with pregnancy, and renal infections associated with kidney or bladder stones or obstructions to the free flow of urine are all included in this group of maladies. They cause great suffering and at times endanger life. They are caused most often by microorganisms that are sensitive to the action of streptomycin. Sixty to seventy per cent of all patients can be relieved either temporarily or permanently with streptomycin.

BACTEREMIAS

When microorganisms invade the blood stream from a local focus of infection, bacteremia is present and organisms can be isolated from the circulating blood. This feature of an infection is always of great importance since it signifies a serious situation. Bacteremia due to a variety of gram negative bacilli has been treated successfully by streptomycin. The blood is frequently cleared of organisms and the local infection is controlled.

Other localized infections that can be controlled in a positive sense are peritonitis and pulmonary infections due to susceptible organisms. The results in typhoid fever and salmonella infections were disappointing.

SUMMARY

In summing up, then, it can be said that streptomycin has taken its place along with penicillin as an effective antibacterial agent in the control of a number of infections. It is an agent that must be administered under the supervision of a physician, and in a small number of patients certain side effects such as a disturbance of equilibrium occur.

Thus, seventy years after the classical and world famous experiments by Pasteur on bacterial antagonism in the study of anthrax, we have at least two powerful agents derived from microbes that can be used parenterally for the control of many infections. Pasteur was the first to advance the subject of bacteriotherapy in the treatment or prevention of anthrax in animals. It is not a little curious, then, that the first two antibiotic agents that have been developed for the treatment of human infections are highly effective against human anthrax.

What of the future? No one can tell, but Patrick Henry once said, "I have but one lamp by which my feet are guided and that is the lamp of experience. I know of no way of judging the future but by the past." The lamp of antibiotics has burned brightly in the past five years. It has illumined the present, and it has sent a bright beam of light into the future.

THE FREEDMEN AND THE SLAVES OF GOD

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(*Read November 21, 1947*)

FOR he that is called in the Lord, being a servant, is the Lord's freeman; likewise also he that is called being free, is Christ's servant. Ye are bought with a price, be not ye servants of men. Brethren, let every man, wherein he is called, therein abide with God.

According to the authorized version of the New Testament these are words which the apostle Paul wrote to his Corinthian congregation in I Corinthians 7: 22–24. The Greek word which is translated "servant" or "servants" in the King James version actually means "slave" or "slaves"; and the word translated "freeman" is, in fact, freedman (*apeleutheros*). This statement of Paul leads me to present for your consideration two problems. The first is one of interpretation. The second is a genetic question. What did Paul have in mind when he made the paradoxical statement that a slave who had accepted Jesus as the Anointed One was the Lord's freedman and that a free man who was converted was a slave of Christ? What was the concept of slavery and freedom back of this statement and from what source did Paul derive the idea?

In 1908 Adolf Deissmann in his famous book entitled *Licht vom Osten* made the brilliant observation that Paul, when he wrote of the redemption through Christ from enslavement to the vices of the body, had taken his metaphor from the law and the popular practise of manumission as it operated among the Greeks. He pointed out how admirably Paul had adapted this metaphorical explanation of the equalitarianism existing in the Christian groups "to the requirements and the intellectual capacity of the lower classes."[1] Slavery was something which Paul's correspondents knew thoroughly. It was all about them, in daily operation in every Hellenistic town and city of that time. Correctly, though perhaps too narrowly, Deissmann connected this metaphor with a method of manumission which had been followed for two centuries before Paul's time at the temple of Apollo at Delphi. This was the practice of granting liberty to the enslaved by means of a trust sale of the slave by his owner to the god Apollo. This was not a "fictitious sale" as Deissmann thought. It was clearly an entrustment sale.[2] Without further discussion of several features of the Delphic manumission process which Deissmann did not understand, one must pay tribute to his learning and his insight in recognizing Paul's statement for what it was. The Corinthians to whom Paul was writing lived in a Greek urban handicraft center in which industrial slavery had always been strong in the field of labor; and Paul's metaphor was a cleverly conceived rhetorical device for making clear his insistence that the Corinthian group of Christians should follow the path of spiritual equalitarianism as between themselves.

Recently Gerhard Sass presented a new understanding of the Greek word *doulos* as used by Paul.[3] One must approach the word in Paul's epistles, he believes, out of his religious-legal Hebrew training as well as from his environment as Roman citizen who grew to manhood in the Hellenized city of Tarsus. The Greek noun *doulos*, according to Sass, designated, in its accepted and customary meaning, a man in an "unnatural" status of dependence to an individual owner or in an "unnatural" condition of subservience to free people taken as a group; and Paul knew and used it in this sense. I must here hasten to deny, categorically, that the institution and the status of slavery were ever considered "unnatural" by the Greeks, or, in fact, by any other people of antiquity. It was as enveloping to them and as natural as the air about them and accepted as readily, completely, and without effort as the breathing of that air. As Sass further develops the idea, Paul employed the word also in a religious sense which

[1] In the English translation of the fourth German edition, *Light from the ancient East*, London, 1927, Deissmann's discussion appears on pages 318–330. In discussing the philosophic aspects of it he accepts the ideas of a brochure by Weiss, Johannes, *Die christliche Freiheit nach der Verkündigung des Apostel's Paulus*, Göttingen, 1902.

[2] Westermann, W. L., in the *Quart. Bull. Polish Inst. of Arts and Sciences in America* **2**: 13, 1943; *Amer. Hist. Rev.* **50**: 215–216, 1945.

[3] Sass, G., Zur Bedeutung von δοῦλος bei Paulus, *Ztschr. für die NT Wiss.* **40**: 24–32, 1941.

was completely foreign to the Greek *doulos*. He derived this use from the Hebrew noun *ebed* and *ebed Jahwe*, "slave of Jahwe," and from *ebed* as verb, meaning "to work." [4] In this Hebrew significance the word *ebed* had eventually taken on the meaning that God expressed his will through chosen men whom Jahwe called his servants. *Ebed*, therefore, expressed an action of Jahwe carried out by his chosen instruments among mankind. The men thus selected to do Jahwe's work were thereby honored so that *ebed* became an honorary title, completely bereft of the idea of subservience. Among these tools and servants of God, whether they were conscious or unconscious of their missions as such, were Moses, Joshua, David, the prophets, Israel, Nebuchadnezzar, and Cyrus the Persian.[5] To Sass, this Hebrew significance was the second, and the dominant, implication lying in Paul's use of *doulos*.

It is not within my linguistic competence to judge the value of Sass's explanation of the implications resting in the Hebrew word *ebed*. That must be left to the Semitists. The whole idea disintegrates, however, when Sass attempts to transfer this meaning to the Greek word *doulos*. There was a perfectly adequate Greek noun, *hyperetes*, with its corresponding verb, *hyperetein*, which would express exactly the indefiniteness of "servant" and "lowly services" implicit in the Hebrew noun and verb *ebed*. These words Paul would have used had he meant to express in Greek the type of non-slave service which Sass has found in *ebed*. This becomes clear from the fact that Sass can do nothing at all with the passage in I Corinthians 7, which I quoted at the outset, nor with the many places where Paul used *doulos* in a similar sense.[6]

It is, of course, utterly unwarranted for us, out of our environment and traditions, to condemn that complete acceptance of slavery which existed throughout antiquity. But it is entirely pertinent to put these questions of fact. Did the ancient Hebrew legislation condemn slavery as such? For tribal-nationalistic reasons, but not from humanitarian reasons, it rejected enslavement of one Hebrew by another Hebrew. For Canaanites and all other non-Hebrews the codes accepted slavery, but between Hebrew co-religionists only a bondage relation could exist. Did Plato of Athens, in his "heart of hearts," reject slavery? [7] For the Good State, as projected in the Republic, the slave system was so fully accepted that it required no discussion. Later, in his aging State of the Laws, he elaborated an entire set of practical regulations upon slavery which that proposed state was to adopt.[8] Did Jesus of Nazareth condemn slavery? He did not. Did Saul of Tarsus reject slavery? No! He accepted it fully, as a legal and economic condition of life, valid even for those communities of believers which he himself established. Did Pope Gregory the Great reject it? On the contrary. He spoke of himself as a slave—"the slave of the slaves of God."

Facing consciously the dangers of over-simplification in formulating any generalization, I nevertheless assert with confidence that the gods of the city-state Greeks of the classic period had no slaves.[9] It is true that they sometimes spoke of the servants who worked in the temples as "slaves of the god"; [10] but what the Greeks actually did for the slave institution was to secularize it and in their earliest literate period, as they later secularized the law by sloughing off its divine connotations, transmuting Themis, law by divine command, handed down charismatically, to Nomos, the laws passed by men. In the same way they took the drama, medicine, and deposit banking out

[4] *Ibid.*, 24.

[5] *Ibid.*, 26–27.

[6] *Ibid.*, 25, under note 2, where Sass is constrained to leave these passages, and Deissmann's correct explanation of them, entirely out of consideration. All of the discussions of the pertinent metaphor in I Corinthians 7, except that of Deissmann, fail to deal with the idea of the *paramone* and the freedman, the *apeleutheros*, of God. For a more correct understanding of the word *doulos* in Paul's vocabulary than that proposed by Sass, see Karl Heinrich Rengstorf's compressed article upon δοῦλος in Kittel's *Theologisches Wörterbuch* II: 264–283, Stuttgart, 1935.

[7] The quotation is from Michell, H., *The economics of ancient Greece*, 150, New York, 1940. Michell's attitude of indignation regarding Greek slavery is not a tenable one.

[8] Plato's views upon slavery have been discussed by Professor Glenn Morrow in a detailed article, Plato's law of slavery, in *Ill. Univ. Stud. in Lang. and Lit.* **25** (3), 1939.

[9] Although this is not categorically stated in these terms, it is clearly implied by K. H. Rengstorf in Kittel's *Theologisches Wörterbuch* II: 267, where Rengstorf says that the Greeks did not express their relation to the divinities in the word *doulos*. Compare his statement, p. 271, that the "divine service" idea was common to all the Semites and the Egyptians. Rengstorf obviously believes that the Greeks did *not* have it.

[10] Pausanias X 32, 12 states that in the precinct of Asclepius in Phocian Tithorea there were "residences for the servants and as many as were slaves of the god."

of the dominant control of the temples and turned them into individual enterprises.[11]

In the *Ion* of Euripides the young boy who was the illegitimate son of Apollo was saved by his divine father from death by exposure and brought up as a servant in his temple at Delphi. Answering a question put to him by his mother, Creusa, whether he had been dedicated to the god by some city or sold to the god by some individual, Ion gave a dubious answer: "I am called, and I am, the slave of the god." [12] When, however, he learned that he was an illegitimate child of a free girl, abandoned by his mother, he said, if that were true, he had escaped slave status.[13] Although Ion is never in the play called a "temple-sweeper" (*neokoros*) that was what he was in fact, a minor official whose service consisted of keeping the temple clean.[14] It has not been pointed out, so far as I have seen, that it was the Delphic citizen body, not the god Apollo, which had appointed Ion, when he grew to manhood, to the position of treasurer of the god and faithful steward of all his possessions.[15] Obviously, in that case he was a civil appointee in the temple organization, not a slave of the god.[16]

The fact that the Greek city-state gods had no slaves is more convincingly apparent in the inscriptions which give us contemporary and irrefutable historical data. In 92 B.C., at the request of the citizen body of Delphi, Nicomedes III of Bithynia sent thirty slaves to the god of Delphi and to the city. It was not the god or his priests who assigned to them their various duties connected with the temple service and its properties. It was the citizen Assembly of Delphi which did so.[17] In the period after Alexander, even in Anatolia where the background and religious spirit was, perhaps, more strongly impregnated with ancient Oriental than with Greek ideas, the temple laborers were servants, not slaves. In the middle of the first century B.C. Antiochus I of Commagene dedicated villages, with their resources, and their *hierodouloi,* to the temples of his kingdom. Literally translated *hierodouloi* means "sacred slaves." But these were *not* slaves, by the explicit terms of the law establishing the dedication. Therein the statement occurs that it was to be unholy "for anyone, either the king or dynast or priest or magistrate . . . to enslave to himself or to transfer to anyone in any way . . . these hierodules whom I have dedicated to the gods at my expense in accordance with the divine will." [18] The hierodules of Asia Minor were bondage dependents of the gods,[19] the degree and nature of their subservience probably differing in details from place to place.

From the precinct of Apollo at Delphi we have more than a thousand manumissions of slaves, from 200 B.C. to about A.D. 75, in which the procedure of effecting the grant of liberation was by a trust sale of the slave by his owner to Apollo.[20] These show several differences of kind, including two important types. In about three quarters of the whole group the slave became outrightly free, with no restrictions whatever imposed upon his future liberty of action. He gained all of the four elements of personal liberty which the Delphic formula envisaged as the substance of freedom. These were: status in the community, protection from illegal seizure, liberty to choose his own work according to his desires, and freedom of movement. Two of these, status and protection from unwarranted seizure, are public rights. Theoretically the free man cannot lose them otherwise than by action of the state, nor can he himself alienate them. The last two of these possessions, economic freedom to choose one's field of labor and the right to go where one listed, are private

[11] Westermann, W. L., *Jour. Egyptian Arch.* **17**: 27, 1932.

[12] Euripides, *Ion,* 309. *Cf.* line 182: "I will act as slave of Apollo and will not cease to serve those who nourish me."

[13] *Ibid.,* 556.

[14] A Russian scholar, A. W. Nikitsky, long ago pointed out that Ion was "a servant." See Ernst von Stern's review of Nikitsky's book, written in Russian, in *Berliner Phil. Wschr.* **16**: 305, 1896. The phrase "consecrated servant" is that used by K. Hanell for the *neokoroi* in his article upon them in Pauly-Wissowa, *Real-Encyclopädie* **16**: 2423.

[15] Euripides, *Ion,* 55–56.

[16] Rengstorf in Kittel, *Theologisches Wörterbuch* II: 267, is right in denying that the Greek verb *douleuein,* as used by Euripides in *Bacchantes* 266 and in *Orestes* 418, contains the idea of slavish devotion to the gods which lies in the Hebrew concept of *ebed.*

[17] Dittenberger, *Orientis Graeci Inscriptiones* I (345): 12–13.

[18] *Ibid.* (383): 171–185. Upon the temple organizations in Asia Minor consult Rostovtzeff, *Social and economic history of the hellenistic age* I: 505–507. They are also referred to extensively in the index under "temples," and discussed by Broughton, in Frank, Tenney, *Economic survey of the Roman empire* IV: 641–642, Baltimore, 1908.

[19] This term is adapted from the description of their dependence given by Hepding in his article *hieroduloi* in Pauly-Wissowa, RE 8, on p. 1466.

[20] The larger part of them are to be found in Collitz-Bechtel-Baunack, *Sammlung der griechischen Dialekt-Inschriften* (GDI), II, and in the *Fouilles de Delphes, Epigraphie,* III 1, 2, 3 (parts 1 and 2), and 6. Scattered examples have been published elsewhere.

privileges of free persons. They are disposable, subject to contractual alienation by the person to whom they belong, or by his representative if the owner were a legal minor.

The second group of the Delphic manumission grants, numbering about one quarter of the total so far edited, is made up of those in which the former slave, now a freedman, agreed to a work contract with his former owner. He contracted to continue to serve the manumitter by carrying out "slave" or "servant" duties, doing every service which he might be ordered to perform, with the important limitation "in so far as he is able." This is succinctly expressed by an adverbial phrase, *to dynaton*. The period of these contractual work obligations is sometimes fixed at a definite span of years, as in any labor contract. More often it is said that they are to continue throughout the life expectancy of the manumitter, or of his wife, or of some other person designated by the former owner. We have over a score of cases in which the manumissions with these continuing indentured services, that is, with *paramone*, are followed by legal and published releases from the obligations thus assumed or by a second contract of sale, called a *novatio*, that is a "renewal" of the contract which eliminated the earlier instrument of sale. The release forms are called *apolyseis*. They frequently state that the release is an extinction of the *paramone* agreement. Never is it said that they are releases from enslavement. These *apolyseis* and *novationes* prove that the life expectancy of bondage services due from the freedman under *paramone*, as envisaged in the instruments of the trust sales to Apollo, was a mere legal phrase indicating only an indefinite period. In most cases the release was made by the manumitter himself, still living and legally active.[21] In other examples it can be shown that the release from the continuing work agreement came within a few years after the original manumission occurred.[22]

Whether the Delphic grants of freedom by trust sale to the god were without any restrictions or were accompanied by continuing services (*paramone*) of the freedman, made not the slightest difference in one essential feature. In both types the sale to the god was often declared to be "for freedom." The work agreement, the indenture for services of the freedman, became a part of the price of liberty paid by him as former slave. In the *paramone* clause the freedman contracted to turn back for a time some part of the two elements of his four freedoms over which, as free man, he exercised control. These were, first, some degree of his privilege of working at whatever he might choose, and second, some part of his complete freedom of movement.

The fact is that the slave who was transferred to the god Apollo by dedication or by trust sale was free by virtue of that entrustment. This is implicit both in the documents without indenture and in those with it; but it is not only suggested. It is definitely stated. In the Delphic archonship of Hybrias, possibly 137–136 B.C., a woman from the central Greek town of Physkos dedicated to Pythian Apollo a female slave "on the consideration that Mnaso is consecrated and not subject to seizure, and free."[23] Accepting the actual wording literally, one would necessarily regard the woman as consecrated to the god, a hierodule. Yet she was, in fact, said to be free. We have two sales to Apollo of the early second century B.C., these with the continuing services of the *paramone*, in which the matter becomes quite clear. In one of them male slaves sold to Apollo are, indeed, to continue their services to their former owner so long as he might live, doing what they were ordered to do. Upon the death of the manumitter they were to "stand as [persons] of the god, being free and not subject to seizure for all their lives, doing whatever they may wish according as they entrusted the purchase to the god."[24] The second case deals with a woman slave. It repeats the phrase quoted above, with the addition that the freedwoman sold to the god, who was to be regarded as "of the god," was also empowered to act in legal affairs in her own behalf.[25]

The published records of the manumissions at Delphi are of several classifications and show some individual peculiarities. A unique variation appears in the freeing of a slave woman in Elatea in Phocis. In its original form her grant of freedom was the deferred type so well known in our South before the Civil War, in which the manu-

[21] *Fouilles de Delphes*, III 3, 2, Nos. 280 and 281, and III 6, Nos. 26–27 and 25 are examples of this.

[22] In GDI 2015 and 1868 the indentured services endured only five, or possibly four, years.

[23] GDI 2097, 6–10. In GDI 2172 a male slave dedicated to Apollo was so dedicated "on the understanding of freedom" (*ep' eleutheriai*). This dedication was actually a sale for a definite sum of money, the amount of which I do not know, called "ransom from the enemy."

[24] GDI 1979, 8–11.

[25] GDI 2006, 4–6. *Cf. Fouilles de Delphes*, III 3, (1) No. 20, of about 140 B.C.

mission is promised, but scheduled to take effect at a later time. The method followed in the case of the Elatean female slave was that of a civil procedure, by a dedication to the god Asclepius and to the city of Elatea.[26] It was announced by the public herald in the citizen Assembly, its consummation being suspended until the payment by the new freedwoman of a sum of money called "ransom from the enemy." [27] It is important in this case to note three facts. The slave woman, formally, was dedicated to the god Asclepius and to the city. Nevertheless she paid for her liberty. The manumission, already published in the precinct of Asclepius in Elatea, was republished in the sanctuary of Apollo at Delphi; and the fine to be imposed upon anyone who attempted to violate the freedom of the woman was to be divided between the city treasury and the god. The dedication to the god, therefore, was actually a profane act, not a religious one.

From numerous towns of central Greece we have inscriptions recording grants of liberty by similar consecrations to some local deity in which the slaves concerned became free by the very act of their dedication. Since they were consecrates of the god, liberation from their enslavement followed from the fact that the Greek gods were not slave-owners. In the long list of divine recipients of these consecrate persons were Sarapis at Chaeronea, Asclepius in the Phocian town of Stiris, Sarapis in Stiris and in Tithora, Asclepius and Dionysus in Locrian Naupactus, Asclepius in Krunoi and Boutti of the Locrians, Zeus of Strattus in Acarnania, Heracles Charops at Coronea,[28] Athena Polias in Daulis, Poseidon of the Tenarium promontory in Sparta, and many others.[29] In Chaeronea [30] and elsewhere the procedure of these dedications was set by a city-state law. This provided that the action in each case must be put through the Council of the city-state. It was, therefore, in effect a liberation by civil procedure with a religious sanction. Above all, the persons thus allegedly consecrated to the god were free.

The *paramone* clause which appears in the priestly publications of the Delphic manumissions which used the procedure of the trust sale to Apollo provided for the continuing services of the new freedman under his own contractual agreement. Among the papyri found in Egypt we have numerous examples of work contracts dealing with the labor of free persons themselves or the leasing out of the work potential of their slaves. These contracts are specifically called *homologiae paramones, paramone* agreements. In a forthcoming paper it will be shown, conclusively I hope, that this Greek contract called a *paramone* differed from other labor contracts largely in the single fact that the services hired by the work giver were not specialized, or defined, in the contract.[31] The *paramone* labor contract, in other words, had to do with general services, unspecified, as contrasted with a contract for piece work or for the hire of a skilled craftsman to carry on his specialized kind of work. The kind of labor involved is that of a "hired hand," or of a "hired girl," to use an old and expressive American term now dignified into disuse as expressing something unworthy of a worker. Just as the new freedman or freedwoman of the Delphic manumissions agreed under his, or her, *paramone* arrangement to continue the general servant duties which he, or she, had carried on under enslavement, so here, the free laborer might bargain away for a fixed term a part of his freedom, the two privileges resting in his choice of work and his right to move where he wished. His labor potential belonged to the work giver for the period contractually defined. His mobility as free person, too, was restricted either specifically or by reason of his work obligations.

In its application, therefore, the *paramone* was a work contract which might operate in two opposed directions. A manumitted slave might not have at his immediate disposal the full amount of money demanded as his self-redemption price.

[26] *Fouilles de Delphes*, III 2, No. 120. In lines 18–19 the woman is called "a freedwoman consecrated to Asclepius and to the city of Elatea."

[27] *Ibid.*, lines 8–9.

[28] Pappadaki, N. K., in *Archaiologikon Deltion* **2**: 218–219, 1916.

[29] The inscriptions are to be found principally in *Inscriptiones Graecae* VII and IX. Many selected examples appear in Dareste-Haussoullier-Reinach, *Recueil inscr. juridiques grecques* II: 234–318. A. Calderini, in his *Manomissione e condizione dei liberti in Grecia*, Milan, 1908, in ch. 2, pp. 108–113, has assembled all the examples of such dedications extant at the time. I find no proof for his belief that the persons thus manumitted had been slaves of the corresponding gods. Turin Papyrus No. 9 certainly does not prove it, as Calderini implies, *ibid.*, 118 and note 2.

[30] IG 7, Nos. 3313 ff.

[31] A number of these are to be found as entries of *paramone* agreements of free persons hiring out their own services, recorded in registers from the Fayum town of Tebtunis in the years A.D. 41–49. The registers were skillfully published by A. E. R. Boak in *Michigan Papyri* II (121–128), 1933, Ann Arbor. See Boak's special Index V, under *paramone*.

Two possibilities then lay open to him. He might borrow the remainder from persons willing to advance the money. In some of the cases in the Delphic group he obtained this as an *eranos,* an accommodation which did not bear interest, advanced by a temporary group of lenders organized for this one purpose. Sometimes the *eranos* group was headed by the slave's own master. If this were not feasible the freedman might agree to do *paramone* services for his former master or for someone whom he, the former slave owner, might designate, until he could save enough to complete the self-purchase already begun. Under the *paramone* contract of free laborers a free man contracted to give over the same parts of his liberty, his labor potential and some part of his privileges of free movement. The *paramone* was, therefore, a two-way street, not one-way. The new freedman might follow its direction out of his servile status toward an unrestricted freedom. The free man might go along it for a time, under restrictions contractually accepted, walking with open eyes into an area of limitations upon two elements of his liberty, those of his free choice of work and of his freedom of movement.

With this understanding of the *paramone* as general service agreement affecting the free laborer and the freedman in the same way one can consistently explain the freedom found by the slave in Christ's service and the enslavement in Christ of the free convert to Paul's faith. With the same acquaintance with the *paramone* as Paul the Apostle had, the Greek and Roman rhetoricians and teachers of ethics, such as the Spanish-born grandee and Stoic, Lucius Annaeus Seneca, and Dion the Golden-mouthed of Prusa, adopted a similar view of equalitarianism as between slave and free. In Dion's second discourse *Upon Slavery and Freedom,* one of the participants in the discussion exclaimed that he could not see how he himself, probably born of free parents, could possibly be called a slave. His opponent, however, might indeed have been a slave who could have become free by a grant of liberty from his master. Or, if he had had the money, he might have redeemed himself by paying his purchase price to his master.[32] In the latter case, which is one of self-redemption with the slave's own money, I am sure that there must have been some method employed of legal evasion of the fact that a slave could not enter into a contract to use the money which he could not legally have, but *did* have, in point of fact. At Delphi this evasion was accomplished by the trust sale to Apollo. At Athens the trust sale to a god was, apparently, not used. There it could be arranged through a collusive court action against the unfree on a sort of fugitive slave charge.[33] The outcome of such a trial was predetermined in favor of the slave, who was formally acquitted and so was declared free.

In the first of his two discourses *Upon Slavery and Freedom* Dion of Prusa shows even more clearly that he was conversant with the Greek concept of freedom as it was expressed in the Delphic formula of the trust sale to a god who had no slaves. Dion there has one of his disputants declare that the person with whom the possibility rests of doing what he wishes is a free man. The one for whom this is not possible is a slave.[34] This is the third of the four elements making up the total of liberty according to the Delphic formula of manumission, the third of the four freedoms which the new freedman had obtained by the trust sale to Apollo. The question of the Stoic understanding of freedom in comparison with that of the apostle Paul was handled in an address given in 1901 at Stockholm by the German theologian, Johannes Weiss. To the Stoics from Chrysippus onward, through Seneca and Dion of Prusa to Epictetus and Libanius, the condition of bondage was accepted as one of the *adiaphora,* one of the things which were indifferent in men's lives and of no real consequence. The Wise Man must have three characteristics, self-sufficiency, lack of sensitivity to mental and physical pain, and impassivity. The Greek terms are, respectively, *autarcheia, apatheia,* and *ataraxia.* The Wise Man who attains to these qualities, and the Wise Man alone, is a free man. In the Stoic teaching freedom, as opposed to slavery, was therefore a set of character qualities and a state of mind.[35] As with the early Christians, with the Roman Stoics legal status had nothing to do with real freedom.

It is true that the Stoics and the early Christians approached one another in their theoretical insistence upon the equality of all men, whatever be their status in life. Seneca expressed it in this way: "Nature bids me help men. Whether they be slaves or free men, free born or freedmen, whether they possess liberty granted by official

[32] Dio Chrysostomus, *Oration* 15, Upon Slavery and Freedom, sections 21 and 22.

[33] See the article, Two studies in Athenian manumissions, in *Jour. Near Eastern Stud.* **5**: 94–99, 1945.

[34] Dio Chrysostomus, *Or.* 15, sec. 13.

[35] Weiss, Johannes, *Die christliche Freiheit,* 20–30.

procedure or by the action between friends—what difference does it make?" [36] Again he says: "He whom you call a slave is sprung from the same seeds as you, he enjoys the sight of the same sky. He breathes, he lives, he dies like you. So you can look upon him as a free man just as he upon you as a slave." [37] For Seneca, slavery did not penetrate the whole being of a man. The mind remains free to wander—"so that it cannot be held even within this prison [of the body] in which it is confined, . . . It goes forth into the infinite to become a comrade of the stars in heaven." [38] In much the same way Paul, the apostle, proclaimed that equality must exist in the common bond of the Christian belief. "There is neither Jew nor Greek, there is neither bond nor free, there is neither male nor female; for ye are all one in Jesus Christ." [39]

Adolf Deissmann was correct in pointing out that the humble records of manumissions furnished by the inscriptions from the sacred precinct at Delphi and, in Egypt, by the finds of papyri, offer a better idea of the course of the figures of speech used in talking of the slaves of the Lord than the fineness of rationalization employed by the philosophers.[40] For the external setting of his metaphor taken from the *paramone* agreement Paul used both the general labor contract of free workmen and the continuing service arrangement of the *paramone* manumissions as seen at Delphi. The free converts became slaves in Christ. The slaves became freedmen; and belief in Christ is the *paramone,* the act which accomplished that result. Conversion, too, like the *paramone,* was a two-way street, leading in either direction, by virtue of God's mercy, to release from the sins of the body. The sole requirement was that one must believe, as Paul so passionately believed and so resolutely taught. In his epistles the technical Greek word for "redemption price" appears nine times; that for "slave" at least a score of times; "freedman" once; "freedom" and the verb "to set free" some ten times.[41] The most significant of all of Paul's verbal borrowings from the Greek *paramone* is its key word, the verb *paramenein.* This Paul uses twice, once in its exact form as compound verb,[42] another time as *menein* followed by *para* governing the dative case.[43] In this latter instance also the derivation from the *paramone* meaning "work contract" is unmistakable. The contract and its service are with God. In the brief letter to Philemon regarding his runaway slave, Onesimus, whom Paul had converted, he does not use the key word *paramenein* because the slave was to return to Philemon still remaining in his previous servile status. The equalitarianism which Paul required of his converts permeates, however, the entire incident. Slave and master, Onesimus and Philemon, are equals "in the bonds of the evangel." Philemon is urged to take Onesimus back "no longer as a slave, but above a slave, a beloved brother, particularly so to me, but by how much more to you, both in the flesh and in the Lord." [44]

For the purpose of presenting Paul's meaning with greater precision, though with less beauty, I translate in my own terms the pertinent passage from the Greek of I Corinthians 7, eliminating the inexactnesses of the authorized version:

> For the slave who is called in the Lord is a freedman of the Lord. Likewise the free man who is called is the slave of Christ. You have been bought for a price; be not slaves of men. Let each man, brothers, remain [in *paramone*] beside God in that status in which he was called.[45]

Here are all of the main features of the *paramone* of the Delphic manumissions. The general service contract is the arrangement of the new convert with the Lord. Free or slave he has engaged himself to do slave, or servant, duties. He had been bought at a price. Hundreds of times in the Delphic manumissions the amount of this price is given. In both cases the technical Greek word, *timé,* is the same. To Paul the price was Christ's sacrifice. Whether free or slave the man thus bought was spiritually free, but bound by his agreement with the Lord. *Meneto para Theōi,* "in this status let him carry on [his service] with God." Even the imperative mode, *meneto,* repeats the constant usage in the Delphic manumissions with the *paramone* clause.

The answer to the question where Paul got this idea of the converts to Christianity as slaves of God, has narrowed itself down by elimination.

[36] Seneca, *Dialogorum,* VII 24, 3.
[37] Seneca, *Epistulae morales,* 47, 10.
[38] *Idem, De beneficiis,* III 20, 1.
[39] NT, Galatians 3: 28.
[40] Deissmann, *Light from the ancient East,* 319 and 320, note 1.
[41] Consult Moulton, W. F., and Geden, *Concordance to the Greek Testament,* Edinburgh, 1927, under the words *apolytrosis, doulos, eleutheria, eleutheros* and *eleutheroun.*
[42] Philippians 1: 25.
[43] I Corinthians 7: 24.
[44] Philemon 16.
[45] I Corinthians 7: 22–24.

The Greek gods had no slaves, despite Pausanias, the second century writer who was probably Lydian born, and despite Ion's statement, in Euripides' play of that name, that he was called a slave of the god Apollo. The fact has been established from a number of the sales of slaves to this same god Apollo at Delphi that the slave sold to him was a free man without benefit of further civil or canonical action.[46] In none of the Greek writers of the classic period except Euripides and the later writer, Pausanias, in none of the extant Stoic diatribes upon slavery, in none of the incidental references to slavery in the ancient literature of Greece, do I recall the phrase "slaves of the God."[47] Paul must, therefore, either have found within himself the religious humility which transmuted the converts to his belief into slaves of God or it came to him out of his Jewish faith and legal training. The assumption would be close at hand, in the second case, that the idea was a Hebrew segment derived from the total Semitic pattern of religious thought which lay behind Hebrew ideals.

The latter decision is, I think, the correct one. The external trappings, all of the details of procedure, the vocabulary, these were derived from the Greek *paramone*. The inner spirit from which came the slaves of God went back to Semitic-Oriental concepts of man in his relation to his gods. The *shirkê* who appear in Neo-Babylonian documents of the sixth pre-Christian century were devotees assigned to the gods, not to their temples. We find them as slaves of Shamash, of Innina of Erech, of the god Bel, and of the goddess Ishtar.[48] It is to be noted that free children could be devoted by their parents to lifelong service to these gods, as well as their slaves. This type of dedication was certainly not unknown to the Hebrews. Witness the consecration of the boy Samuel by Hannah as a lifelong loan to the Lord[49] and the "numinous relation" of the servant of the Lord in Isaiah 53: 11.[50]

There are several fundamental distinctions which should be made between the institution of slavery as it appeared in the Semitic pre-Greek world and its structure in the world of the Greek city-states. Two of these differences are vital to any comparative study. The first is that all Semitic slavery was national-tribal. In the Code Hammurabi a sharp distinction is made in respect to a co-tribal Ammorite, who might fall into bondage to a fellow Ammorite, but not into slavery to him.[51] The non-Ammorite who was captured or bought became a slave. In the Middle Assyrian Law Code it was the same. In the Hebrew law the co-religionist might become a bondsman of a fellow Hebrew; but he was released from his bondage in the year of the Jubilee. The Canaanites and other non-Hebrews could be enslaved. The Greeks, on the contrary, completely de-nationalized slavery. Plato might think it unseemly for Greeks to enslave other Greeks; but he did not carry this idea beyond the stage of a mild protest. The Delphic reports upon manumissions often give the native country or town of the slave sold to Apollo, though this was not a consistent practice. A cursory glance at the records proved to me that there were scores of slaves of Greek origin, not including the many "home-born" slaves, who might be of any kind of parentage. Two of the manumitted slaves came from Delphi itself and a number from the neighboring towns of Boeotia. The second point of important difference is that the Greeks secularized the slave institution. Individuals had slaves. A number of the city-states owned public slaves. But the gods did not have them.

Understanding of the dual source of Paul's idea of the slaves of God—its methods from the Greek *paramone*, its spirit out of the Semitic world of ideas—offers a new approach to one problem of Hellenistic religious practice which has long been disputed. This related to the *katochoi*, a group of religious devotees known, from papyri dating from the second century B.C., to have been connected with the temple of Sarapis. These *katochoi* lived in the temple precinct of that god on the

[46] For the view that the Greek dedications (*anatheseis*) of slaves to various deities were nothing more than another of the methods of manumission consult Paul Koschaker in *Abh. sächs. Akad. Wiss., ph-hist. Klasse* **42**: 74.

[47] It does not appear in Cleanthes' *Hymn to Zeus*, in the fragments of Chrysippus, in Seneca's *Moralia* or *Epistles*, in either of Dio's discussions of *Slavery and freedom*, or in Libanius' *Oration* 25, Upon slavery. Philo of Alexandria employed the phrase rather plentifully, as Paul did occasionally, Philo, too, being a Hellenized Jew. See Rengstorf, in Kittel's *Theologisches Wörterbuch* II: 272, for Philo's attitude.

[48] Documents to this effect have been published and the problem discussed by R. P. Dougherty, The sirkûtu of Babylonian deities, in *Yale Oriental Series, Researches* **5** (2), 1923.

[49] OT, I Samuel 1: 11–28.

[50] For the servant of the Lord, as this appears in Isaiah 53, consult Davidson, A. B., *Old Testament prophecy*, 631, 1903, and Smith, W. R., *Lectures on the religion of the Semites*, 554 and 629, 3d. ed., 1927.

[51] *Code Hammurabi*, sec. 117.

desert's rim west of Memphis. In following the new approach to the *katochoi*, we must combine, as Saul of Tarsus did, the Oriental, non-Greek idea of free persons who became slave-devotees of some god, and the Greek idea of the contractual practice of *paramone* by which free persons might give over to others two parts of their privileges as free men, the selection of their work and their liberty of going where they wished. The word *katochoi* means, when bared to the roots, "those held down." They were "detainees" of the god Sarapis, self-devotees. While subject to the sacred detention thus self-imposed they could not move out of the sacred precinct; but they could be released from detention just as freedmen under *paramone* in the Delphic manumissions and the free man hired under *paramone* contract in Egypt were released from their contractual obligations.

In 1920 W. H. Buckler, W. M. Calder, and W. K. C. Guthrie collected a group of surface inscriptions in southwestern Asia Minor. Among these were nine examples from the late second and early third centuries after Christ which the editors explained as deeds of manumission by the process of dedication of the persons concerned to the god Apollo Laermenus.[52] This explanation would bring the documents into the same general classification as the scores of manumissions which we have from towns in central Greece by dedication to some Greek god. The Asia Minor inscriptions cannot be manumission documents. No technical word appears in them which might warrant that conclusion. Quite to the contrary. The legal word used by the persons who inaugurate the action is *katagraphō*. This means: "I transfer by deed," or "I convey [this person] to Apollo Laermenus." [53] Among these transfers found at ancient Dionysopolis and published in MAMA IV, I find five slaves (one slave boy and four slave girls) legally conveyed to the god. Also one free girl and five free boys are transferred to the god and in precisely the same terms as the slaves. In all the cases of these free children the persons making the legal transfer to the god were their parents. I translate one of these conveyances (*katagraphai*):

> Year 289, 4th month, 19th day. I, Diomas, son of Daphnus, priest, convey my offspring and my heir, Diomas, to Apollo Laermenus, the Sun God. If any one shall enter an action against [this transfer] he shall pay as fine to the god 2500 denarii and likewise to the fiscus [Roman imperial treasury] 2500 denarii. Good luck.[54]

The explanation offered by the editors in this instance was that the offspring of the conveyor was probably his son by a slave woman. This was a necessary refuge out of the difficulty created by regarding all of the documents as manumissions. Certainly these are nothing more than child oblates, free or slave children, as the case may be, dedicated to the god's service.[55] Paul would have understood these dedications of children at the Hellenized town of Dionysopolis, situated not much more than three hundred miles west of his native city, Tarsus, for exactly what they were. To him they would have been typical of that Oriental class of devotees from which he drew, in I Corinthians 7, the metaphor of the free men who became slaves of the Lord.

Demanding from himself as from other converts the great humility of complete and slave-like subservience to Christ's teachings, Paul begins several of his epistles thus: "I, Paul, slave of Jesus Christ." [56] From him this non-Greek concept of devotion to God goes into the church. Clearly its use appears in Augustine's Epistle to Vitalis: "Bishop Augustine, slave of Christ and through his own volition slave of his own slaves." [57] Pope Leo I adopted the title in a letter to the Emperor Theodosius. Gregory the Great entitled himself "slave of the slaves of God." [58] In that form the tradition has been maintained in the bulls issued

[52] *Monumenta Asiae Minoris Antiqua* 4, Manchester, 1933, Nos. 275 BI and BII: 276 AII, AIII; 276 B; 276 C; 277 AII; 277 B; 278 I. I do not include 278 II because it is fragmentary and too uncertain. Two similar documents, possibly from the same sacred precinct, were published by W. M. Ramsay years ago in *Jour. Hellenic Studies* **4**, 380–381, Nos. 3 and 4, 1883. They dealt with slaves who were consecrated, not with free persons.

[53] For the *katagraphe* in the papyri as a legal conveyance see P. Petrie III No. 23, 2 (p. 70); BGU I 50, line 8; P. Oxy XIV, No. 1636 and note to lines 42–43; 1697, 33 and note; 1703; and J. Partsch's explanation of the *katagraphe* in his discussion of P. Freiburg 8.

[54] MAMA 4, No. 270 B.

[55] These child offerings are dealt with by Mitteis, L., in his *Reichsrecht und Volksrecht*, 55; by Bell, H. I., in *Jour. Egypt. Arch.* **8**: 93, 1922, and above all, by Steinwenter, Kinderschenkungen, in *Ztschr. Savigny St., Kanon. Abt.* **42**: 175–202, 1921. They correspond to the *shirkê* in Dougherty's Sirkûtu of Babylonian deities, *Yale Oriental Series, Researches* **5** (2). T. R. S. Broughton in *Economic survey of the Roman empire* IV: 682, still regards these examples of child offerings as emancipations.

[56] I Romans 1; I Philippians 1. Titus 1 begins: "Paul, slave of God, apostle of Jesus Christ."

[57] Augustine, *Ep. 217, ad Vitalem*, Migne, J.-P., *Patrologiae Latinae* XXXIII: 978.

[58] Dudden, F. H., *Gregory the Great* II: 280, London, 1906.

by the Popes to this day. Pius XII, for example, still speaks of himself under the humble designation of *servus servorum Dei.*

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ENVIRONMENT AND CULTURE DURING THE LAST DEGLACIATION

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PERIOD OF DEGLACIATION VERSUS POSTGLACIAL TIME

In the prehistory of man, we are accustomed to divide glacial from postglacial time as though we were using a common point of reference. Actually we bring on ourselves no little confusion, since the end of glaciation differs greatly from place to place; there is also no agreement by different students as to the terminal event selected. An event of local significance serves as a datum line satisfactory for the local history, but is incompetent for any general chronology. In Scandinavia DeGeer proposed a date of nine thousand years before the present as the beginning of postglacial time, and this date has been used widely, and far away from that peninsula. Yet the date, if correct, marks only the detachment of the ice cap on the Scandinavian Highland into two separate masses (the so-called bifurcation). It may be a convenient marker in dating the Scandinavian past, but even there other workers have preferred other, earlier events for the beginning of postglacial time, nor is the bifurcation a critical turning point in the physical history of Scandinavia. Someone's good local date unfortunately may become someone else's wrong date elsewhere by unawareness of the locally limited validity of the datum.[1]

There are indicated, however, two late moments of earth history as sufficiently brief, significant, and general to serve as critical markers of time. The first is the beginning of the great deglaciation [2] following the last major ice advance; the second, its ending. The former is here taken as dating about 35,000 years back; the latter around 7,000 years ago. Both estimates will be examined later.

During this time there was a general glacial deficit; we know of no widespread readvance of the ice. There were halts in recession, probably brief, perhaps local, and an occasional local advance, but nothing that contradicts the general record of continuing and world wide failure of the ice masses in intermediate latitudes and altitudes, a loss that continued until ice margins had retreated to positions in high latitudes and altitudes not greatly different from the present. The beginning, course, and end of this deglaciation are part of one process, connected with general climatic change.

The present paper is limited to events thought to belong after the last ice culmination and before the end of the major glacial retreat, and the period included is here estimated as being somewhat in excess of 25,000 years. Into this period falls the cultural revolution known as Mesolithic; the coincidences of great environmental and cultural changes are thought to be connected.

THE ISOSTATIC REGISTER OF DEGLACIATION

Both in North America and Europe the maximum extension of the Fourth Glaciation (Wisconsin of North America) was early in that stage: in Europe the Warthe and Weichsel-Brandenburg (?) substages, in eastern North America the Iowan and Tazewell, and in the western mountains probably the Tahoe. Later there was a major readvance, in North Europe both Frankfurt-Posen and Pomeranian, around the Great Lakes the Cary, and in our West the Tioga.[3] Time equivalence of the substages around the northern hemisphere is conjectural, but the general deployment of the Fourth Glaciation was of sufficiently similar pattern in all three areas to indicate that a correlation exists.

[1] Flint, R. F., *Glacial geology and the Pleistocene epoch* (N. Y., Wiley, 1947) has a good discussion of the Pleistocene-Recent boundary (pp. 205–208). This informed and judicious volume, together with F. E. Zeuner, *The Pleistocene period* (London, Ray Society, 1945), *Dating the past* (London, Methuen, 1947) by the same author, and Diluvial-Geologie und Klima (*Geol. Rundschau, Klimaheft* **34** (7–8), 1944), edited by Carl Troll, summarize present knowledge of the Ice Age and its aftermath.

[2] See Russell, R. J., Quaternary history of Louisiana, *Bull. Geol. Soc. Amer.* **51**: 1201, 1940.

[3] I am departing from usual interpretation in suggesting that the western Tioga may bracket with eastern Cary rather than with Mankato. The reason is made apparent below.

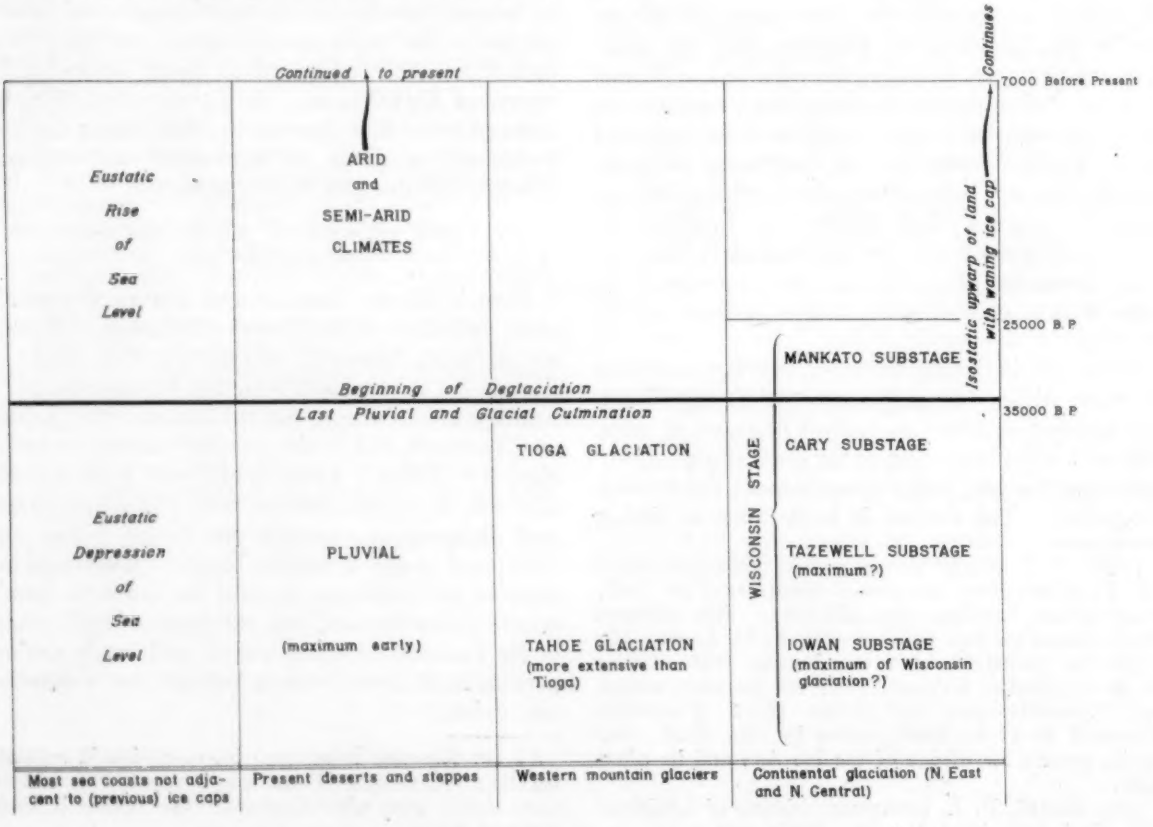
Subsequent events appear to belong to the time of deglaciation:

(1) The latest glacial substage in the eastern United States is now called the Mankato, to which an estimated age of 25,000 years is assigned. As at present interpreted, east from Minneapolis to Lake Ontario, it is mainly recessional, like the Scandinavian moraines. Westward, however, in the long and narrow Des Moines lobe, there was a curiously belated violent outburst of ice, which is one of the most puzzling features of glacial history. The explanation of the Des Moines salient, jutting far south from the continental ice margin of its time, remains to be found.[4] The Cary substage, most familiar in the Valparaiso moraine festooned about the south end of Lake Michigan, is held to be the last ice culmination, the Mankato to belong to the time of deglaciation.

The existence of the Des Moines salient is hardly sufficient reason to assign the late (Tioga) mountain glaciers of the West to that moment of time, as has been done. Two probable Wisconsin substages have been recognized widely in the western mountains, as far south as the San Francisco mountains of Arizona.[5] Differences in their

[4] More knowledge is needed of the Late Mankato glaciation, especially for the Dakotas and the Canadian prairie provinces. Their climatic conditions can hardly be reconstructed from the data we have. If I understand the situation for Late Mankato time rightly, the great ice mass of the Northeast, from the Great Lakes to the Atlantic seaboard, was being thinned and driven back strongly, but over the northwestern plains a comparatively thin and short ice margin was briefly reenergized. An accumulation of snow pack over Alberta, Saskatchewan, and Minnesota resulted from vigorous passage of winter air "fronts" across them, with deep northern interior penetration of moist, relatively warm Atlantic air. Both profile and outline of the Des Moines and Grantsburg morainic lobes suggest such inflows out of the East. The atmospheric circulation pattern involved in the final Mankato glaciation seems to me to involve the operation of air cells and oceanic circulation over the Atlantic as beginning to approximate contemporary conditions and not those that initiated the great deglaciation and the end of Pluvial conditions in the Southwest.

[5] Sharp, R. P., Multiple Pleistocene glaciation on San Francisco Mountain, Arizona, *Jour. Geol.* **50**: 481–503, 1942.



Schematic Representation of Late Pleistocene Time for the United States

FIG. 1

weathering establishes the Tahoe as significantly older than the Tioga stage. The very widespread occurrence of both stages suggests that both belong to times of general extension of glacial conditions, and hence that the later one may correlate with the Cary of eastern North America, rather than with the Mankato substage.

(2) A safer guide to the waning of glaciation is to be found in the isostatic upwarping of the Earth's crust in areas formerly covered by continental ice. The forming of continental ice caps depressed the underlying bed-rock; shrinkage of ice cap was followed by reelevation of the land that had been ice-buried, the amount of crustal upwarp apparently being proportional to the weight or thickness of the ice that was removed. Deglaciation and isostatic upwarping thus go hand in hand, the crustal compensation lagging behind the melting of the ice, as is shown by the continuation of upward movement to the present of the crust in northern Scandinavia and in Canada.

The isostatic change is read mainly from the deformation of late glacial and postglacial strand lines. In northern Europe the southern limit of upwarping is along a line from Lake Ladoga through the southern Baltic and the Bristol Channel. In North America the "hinge line" of no crustal change has been traced from the shores of Newfoundland and Nova Scotia through Long Island Sound, across southern Lake Erie and Lake Michigan to North Dakota.[6] This hinge line is well to the south of the post-Cary moraines except for the Des Moines lobe. The warped strand lines of the ancestral Great Lakes show that the crustal upwarp began "early in the Mankato substage. At that time nearly half the Great Lakes region had already been relieved of its load of ice."[7] From glacial Lake Whittlesey on, the succeeding ice-margin lakes were warped during, as well as after, the Mankato period and record therefore progressive and major deglaciation. Not only was the ice front retreating but the ice mass was being greatly reduced. It is apparent therefore that the continental ice cap was in general in full process of destruction during Mankato time, and that the decisive turn of events in glacial history came before, not after, this substage. It is for this reason that I am assigning the beginning of deglaciation to about 35,000 years before the present, by adding ten thousand years for the span from Cary to Mankato, a guess that may be wide of the mark. The isostatic history of northern Europe appears to parallel that of our continent.

[6] Flint, 418–421.

[7] Flint, 423.

LATE GLACIAL AND PLUVIAL CLIMATES

The general circulation of the atmosphere, a heat engine maintained by solar radiation and Earth rotation, forms a more or less permanent latitudinal pattern of climates, which can shift only within limits set by the limits of variability of the general circulation. The most serious alterations recognized in this circulation are those of glacial times. The displacement of climates at such times, however, does not involve the substitution of a different mechanism, nor has it been thought to necessitate the elimination of any of the zonally distributed cells of air masses.[8]

It is not in place here to consider the causes of glaciation, but only conditions before and at the beginning of the late deglaciation. The growing continental ice sheets are thought of as distorting the normal climatic pattern by crowding extratropical storm tracks equatorward. A belt of unstable air is thus construed as marginal to the continental ice fronts; here masses of cold and warm air jostled and mingled, producing frequent precipitation and much cloudiness. Along and behind the ice front the disturbed air brought increased snowfall; before it there was also increased precipitation and overcast. The ice front continued to push its storm belt ahead of it and thus to advance until a latitude was reached in which ice melt balanced snow accumulation.

Such an effect is not adequate to explain pluvial climates at a great distance from ice fronts and in a geographical position normally unfavorable for rainfall. An ice front situated in Minnesota and Saskatchewan, or even Iowa, can hardly be the primary cause for the former pluvial climates that prevailed over the intermontane basins of the West and across the Southwest to and beyond the Mexican boundary.

The evidences of a time of markedly higher moisture are found throughout our arid and semiarid West, Southwest, and adjacent Mexcio, and it is to them that the term "Pluvial" is applied. The Mohave and Arizona deserts of the Southwest have numerous dry lake beds that then held fresh-

[8] Simpson, Sir George C., Possible causes of change in climate and their limitations, *Proc. Linnean Soc. London*, 152d Sess., 190–219, 1939–1940. Contains a strong criticism of the Milankovitch thesis of thermal change, currently in vogue in European glacial geology and among archeologists interested in an "absolute" chronology.

water lakes and marshes, evidences of perennial streams where water now rarely runs, caves now dry that have at depth drip stone, under which are remains of extinct fauna. For instance, the Ventana Cave in the middle of the Papago Desert of Southwestern Arizona has yielded from depth remains of ground sloth, bison, horse, tapir, and man. Where now there are severe desert conditions, then browsed large herbivorous mammals of species now extinct and dependent on a vegetation unlike the present. These were hunted by man, who made his camps by vanished lakes, springs, and streams.[9]

The discovery of man in our Pluvial record has given rise to reduced estimates of the time involved. The Pluvial conditions are still conceded to have been far-flung effects of glaciation, but it is now the mode to say that this Pluvial time must have lasted well into "postglacial times." Thus the sites of Pluvial Man are most likely to have assigned to them an age around ten thousand years or a little more. This revision of the Pluvial dating is due solely to the discovery of the presence of man. It would seem more proper to revise opinion as to the age of man in the Southwest than to reinterpret its physical history to suit preconceptions of antiquity of man in the New World. The supposed lag of Pluvial conditions remains unsupported by evidence, unexplained in principle, and is a solution in dilemma only in order to accommodate traditional views of American prehistory.

Additional light is shed on the Pluvial problem by the neglected situation in lower latitudes, in Mexico. The basins of northwestern Chihuahua held a series of extensive and deep freshwater lakes, possibly comparable in size and history to Lake Lahontan, though without any contributing glaciers. In the heart of the formidable desert of Lower California we (University of California) have found a number of small dry lake beds, at elevations above two thousand feet, and unsupplied by mountain drainage. Their physical and cultural features parallel closely the history of the dry lakes in the Mohave desert. Thus Dry Lake Chapala, at Lat. 29°20′, is in the most desolate part of the peninsula, now lacking water and food or feed for minimal human needs. It is surrounded by beach lines and benches of two or more levels, and formerly had an outlet. We have had opportunity thus far only for reconnaissances, but we know that there was human occupation in force both at lower and higher lake levels, the cultures differing by level. The human remains in and behind the old strands are fairly abundant and indicate camp sites of respectable size and duration. The occupants were hunters and food-grinders, and the later cultural horizon is identified provisionally with the Pinto-Gypsum culture of the Mohave desert.[10]

The desert of Lower California is an effect of the Subtropical High that lies adjacent over the Pacific. If circulation of atmosphere during glaciation involved a narrowing of pressure cells, as is held by some, the desert would still have been in the middle of Lower California, then as now. If glaciation involved a major equatorward displacement of the descending air, we are in fresh difficulties to explain the Pluvial lake basins of Durango and the Valley of Mexico.

It would seem that these Subtropical Highs went out of business during Pluvial time, at least in so far as the land mass of North America was concerned. The air that brought marked increase of humidity to northern Mexico, the Southwest, and the Intermountain Great Basin must have come mainly from tropical oceans, especially from the Pacific, and this freer penetration out of the South would seem to require greatly weakened Horse Latitude cells. The problem of the Pluvial is far greater than any by-effect of continental ice sheets. Glacial and Pluvial climates are locationally distinct expressions of a former general circulation, with a critical difference as against the present in the behavior of that mechanism at the tropical margins.

Change in mountain barriers is negligible at this late time. The probable existence of a land barrier across Bering Strait would bar cold Arctic waters from discharge into the northern Pacific and affect to some extent sea temperatures, but this alone would seem inadequate to reduce greatly the Subtropical Highs.

Modern climates begin with the present position and dimensions of the Subtropical Highs; desiccation in the West and South and deglaciation in the North and the high mountains resulted. Deglaciation required a long time for the removal of continental ice; desiccation followed quickly upon the change in circulation. If we are correct in thinking that the turn of climatic dynamics came with the end of the Cary substage of glaciation,

[9] Late summary by F. H. H. Roberts, Jr., The New World Paleo-Indian, *Ann. Rep. Smithsonian Inst.*, 403–433, 1944.

[10] Determination tentative, by William Massey.

we may suggest that the deserts and steppes of most of the West and of Mexico were established then. Instead of a "lag" in climatic change in the South, the change should have come earliest there. The whole record of the Pluvial time has been placed far too late in American archeology. It should be antecedent to deglaciation, and it may well fill the whole of Wisconsin time from Iowan to Cary.

EUSTATIC RISE OF SEA LEVEL

Deglaciation restored water to the sea in sufficient volume to cause a notable rise in sea level. This late transgression of the sea, sometimes called Flandrian, is world wide because the seas are connected. Locally it may be cancelled out by vulcanism, diastrophism, or more widely where the isostatic upwarp of formerly ice-weighted land has exceeded the rise of ocean. Observational data indicate that the rise of sea level is at least 250 feet.[11] A late study, made for the Mississippi River Commission, indicates a rise of the Gulf of Mexico by 400 to 450 feet.[12]

This transgression reduced the width of coast plains, made shallow seas of some of them, such as the North Sea, South China, and Java seas, and made islands of continental peninsulas, such as Great Britain, Sumatra, Java, and Borneo. Away from the former ice caps, the 50 fathom line gives in rough outline the position of coast line at the start of deglaciation. The greatest loss of land to sea thus would have been between Southeastern Asia and Australia, on the Atlantic Coast of North America from the Banks of Newfoundland to the Mosquito Bank off Nicaragua, and in the South Atlantic from Rio de Janeiro to Patagonia. Lower courses of streams were drowned to form estuaries and bays, and smooth coast lines replaced by increasingly irregular ones.

The process of transgression, though neither uniform nor quite continuous, dominated from the beginning of deglaciation, it would seem, until about seven thousand years ago. Then, in the Atlantic phase of the Blytt and Sernander chronology, modern sea levels were approximated in Northwestern Europe.[13] Since then there have been brief and local fluctuations, but no overall trend is recognized. By inference the general retreat of glaciers ceased at that time, and the remnant ice caps had been reduced mainly to Antarctica and Greenland and Northeast Canada, as now. From this time of near stabilization of sea level dates the beginning of the present detailed physiognomy of sea coasts, the cutting of present sea cliffs, building of spits across lagoons, modern beaches and bars, the forming of our salt marshes.

CLIMATIC AND VEGETATIVE CHANGES

The thesis has been advanced above that a major climatic change initiated and thus preceded glaciation. During the earlier part of the deglaciation (Dryas time) cold periglacial conditions prevailed in northern Europe, as shown by solifluction earths and tundra vegetation and fauna. However, these latitudes are subarctic or nearly so. In North America no such periglacial effects have been found, possibly because of incomplete study, but perhaps because glaciation extended into lower latitudes than in Europe. Several human sites of Mankato age around the Great Lakes indicate that men were living close to the ice margins, as on the Algonquin beach near Killarney, Ontario, and at Brown's Valley and Pelican Rapids in western Minnesota.[14] Apparently, they experienced no climatic or provisioning difficulties in moving up as the ice receded. It may also be significant that neither in North America nor in Europe were loess deposits associated with the deglaciation, or with the final phases of the last glaciation.

The climate of the period is read mostly from the changes in the peat beds, as by analysis of pollen. For North Europe consistent trends in plant succession have been established; our postglacial climatology is less advanced as yet by parallel studies.[15] The existence of the so-called "Climatic Optimum" seems established, a time when certain plants reached higher latitudes and altitudes than at present. In Europe a dozen or more species are involved, including oak and hazel. The conclusion is that more warmth was then available, perhaps warmer summer weather or a somewhat earlier spring, or both. The time of this optimal condition has been estimated variously, ranging from 8000 B.C. for southern Germany to 4500 B.C. for southern Sweden and as little as 1000 B.C. for Denmark and New England.[16] Some of the dif-

[11] Flint, 444–448; Zeuner, *Dating the past*, 128–129.

[12] Fisk, H. N., Geological investigations of the alluvial valley of the Lower Mississippi River, 68, War Dept., Corps of Engineers, 1944.

[13] Zeuner, *Dating the past*, 92–98, 340.

[14] Noted by Sauer, C. O., A geographic sketch of early man in America, *Geog. Rev.* **34**: 539, 1944.

[15] Latest contribution by H. P. Hanson, Postglacial forest succession, climate, and chronology in the Pacific northwest, *Trans. Amer. Philos. Soc.* **37** (1): 1–130, 1947.

[16] Zeuner, *Dating the past*, 67–68.

ferences in time, especially the contradiction in the Danish and Swedish dates, suggest observational error.

The peat studies are in the main of bogs on surfaces uncovered by the last deglaciation and colonized by successive waves of plant immigrants. It would be incorrect to associate each ecologic change with climatic change; most of the record can be accounted for as one of normal plant succession appropriate to the location. Birch and willow are superior pioneers in the higher latitudes; conifers follow and are gradually replaced by mixed hardwoods. The more fertile mineral soils developed most rapidly an enriched and enlarged soil-biotic complex; sands and wet surfaces retained longer less exacting plant species. Progressive drainage gradually improved aeration and humus development. The plant successions that have been preserved in peat pollens may trace chiefly therefore differences in edaphic alteration, in competition between species, and in their mutual accommodation.

The botanical record supports a "xerothermal" period during deglaciation, with "continental" characteristics for those latitudes, in reduced cloudiness and humidity, and with moderate summer warmth. There is no certain evidence of any general climatic change within the period of deglaciation, the whole of which may have had the same meteorologic structure that initiated the deglaciation. The Climatic Optimum may record merely the edaphically and synecologically delayed attainment of climax vegetation, attained only towards the end of deglaciation. It may, however, register a modest increase in growing season and warmth in high intermediate latitudes.

Later, and perhaps after the time with which we are concerned, a certain deterioration of growing conditions occurred in Northwestern Europe and in Northeastern and Northwestern America. There was less summer warmth, possibly owing to more "marine" conditions. A connection with the dying out of the process of deglaciation and freer entry of Arctic water into both Atlantic and Pacific seas, of course, may be suggested. The time of these occurrences, however, is later than the period under discussion.

In summary, during the great deglaciation, no continuing or general readjustment of climates needs to be inferred. The meteorologic shift that terminated the last glacial culmination may be adequate to account for the subsequent climatic conditions until the end of the Climatic Optimum, although a minor positive thermal change cannot be ruled out.

ENVIRONMENTAL CHANGES

For man the time of waning ice sheets brought great and rapid alteration of environment throughout the world, for the most part offering increased opportunities, but in some areas reducing the possibilities of living:

(1) According to the view here presented, the deserts and steppe lands of the present were in existence in the beginning of deglaciation. Except on alluvial lands, mesophytic plants had given way to xerophytes. Most of the big game had disappeared from the more arid parts, and with them the hunting folk. Primitive collecting people of unspecialized habits held on, their habitation sites restricted because water could be secured at fewer places. These sites in general were those where water is found now. Cultural regression may have taken place, but more likely there was cultural and racial substitution by less exacting folk.

(2) The recession of ice sheets uncovered millions of square miles of land in higher latitudes, which became available promptly for human colonization. No unvegetated interval is known, nor have tundra conditions been found within the United States. Morainic and ice-scoured surfaces held very many lakes, ponds, and marshes, rapidly stocked with aquatic and semi-aquatic life. The world population of migrant water fowl increased hugely with the addition of great northern breeding and summer feeding grounds. Such increase was reflected in lower latitudes by improved hunting and trapping opportunities along flight routes and in wintering grounds. Northern woodlands, wet prairies, and marshes became major big game ranges (bison, deer, elk, moose, musk ox), compensating for loss of range in arid lands.

(3) The transgression of sea on shallow continental margins crowded back the inhabitants of coast plains. For primitive man the loss of area was perhaps more than made good by the improved attractions of seashores. The more the sea rose the more sinuous did the shore line become and the more diversified. Increased length of coast line made it possible for more people to live as strand collectors. Drowning of valleys increased the tidal range and thus the vertical zone between high and low tide, which is most valuable for food collecting. Encroachment of sea on land of moderate or even slight relief gave added diver-

sity of bottom and strand: rocky shelves, gravel, sand, and mud flats all acquired distinctive useful faunas. The forming of quiet, land-locked bodies of water gave a favorable setting for early trials in navigation.

(4) Alluvial valleys grew in length and breadth, burying flanks and spurs of the older erosional valleys, as has been fully documented for the Mississippi and its lower tributaries. This was a time of major growth of flood plains wherever streams discharged into the ocean, and thus of growing meanders and relict ox bow lakes, gradually to be filled with sediment and organic matter, of natural levees and backwater swamps. Levee and higher land adjacent to flood plain afforded habitation sites, relocated from time to time as alluviation proceeded.

Marshy parts of the flood plains were colonized by plants, many of them of high usefulness to man: the great perennial grasses that yield canes and reeds and palatable shoots and seeds, rushes and sedges (among the latter some, such as species of Cyperus and Eleocharis, that form edible tubers), various species of the Arum, Iris, Canna, and Water Lily families, with esculent roots, stalks, or seeds. In southern Asia in freshwater marsh margins sago and rattan palms are of importance. The well-drained alluvial lands are optimal sites for plant growth and here useful mesophytic species are found in maximum diversity, including in warm lands species of yams (Dioscorea), Manihot, Maranta, Ipomoea, that store starch in underground stems and tubers.

A new world took form, developing the physical geography that we know. The period was one of maximum opportunity for progressive and adventurous man. The higher latitudes were open to his colonization. In mild lands river valleys invited his ingenuity. It was above all a rarely favorable time for man to test out the possibilities of water-side life, and especially of living along fresh water.

MAN IN THE NEW WORLD DURING DEGLACIATION

The time and order of events, as presented, disagree with the views of American archeology, which has held to the premise that the entry of man into the New World is "postglacial," and is inclined to place any early site from ten to fifteen thousand years ago, about the earliest time at which a recessional corridor might have opened in the Canadian Northwest to admit immigrants from Asia. Against such view is the evidence for a true Paleolithic position of the Pluvial human sites, which preceded the deglaciation and some of which may belong to an early Wisconsin stage. These Pluvial finds are the greater part of the known early human record in North America; they are here excluded as anterior to the time under consideration.

The sites of Mankato age, related to recessional lakes from Minnesota to Ontario, are within the time of deglaciation, but too early for postglacial landwise immigration out of Asia. They are here considered as of epigonous Paleolithic folk whose ancestors were living elsewhere in North America during the last glaciation. The Abilene, Texas, material of the Elm Creek-Nugent horizons probably also is a belated continuation of American Paleolithic. The view that the Wisconsin ice in its retreat opened a land corridor for Asiatic pedestrian immigrants not more than fifteen thousand years ago I find quite acceptable, but not the opinion that such immigration was of extraordinarily delayed archaic cultures.

After the corridor opened, some of the great cultural changes, known as Mesolithic, that had been sweeping the Old World, found their way into the New. Both new culture elements in the archeology and their stratigraphic position suggest that we may have such Mesolithic in the Early Culture of the Central Valley of California,[17] and in the San Pedro Stage, possibly even the Chiricahua stage of the Cochise Culture in Arizona.[18] If there were available immigrants possessed of boating skills, they could have used the Northwest Coast Route at any time.

THE MESOLITHIC ARCHEOLOGIC RECORD

In Europe the last glacial age saw successively the rise and waning of Aurignacian, Solutrean, and Magdalenian cultures. With the onset of deglaciation the Magdalenian faded and new modes came in from North Africa and the Near East, heralds of Mesolithic life. The Upper Paleolithic hunters of big game, masters of stone-

[17] Lillard, Jeremiah B., R. F. Heizer, and Franklin Fenenga, An introduction to the archeology of Central California, *Sacramento Junior College, Anthrop. Bull.* 2, 1939.

[18] Sayles, E. B., and Ernst Antevs, The Cochise culture, *Medallion Papers* No. 29, 1941, and Sayles, E. B., The San Simon Branch, Excavations at Cave Creek and in the San Simon Valley, I; Material culture, *Medallion Papers* No. 34, 1945, but interpreted very differently by the authors.

blade making, and probably strongly masculine societies, left some legacies to Mesolithic habits, but mainly the latter originated elsewhere, and had a very different cultural configuration.

We need not look to the old hunting folk as distant forbears of later planters; we do turn to the Mesolithic record for the earliest background of agriculture. It is still held, but without evidence, that hunters, by increase in their numbers and decrease of game, became farmers. One line of evidence from the Upper Paleolithic is, at first sight, persuasive, the Venus statuettes. These have been interpreted as fertility idols, called Earth Mother figures, and thought of as a sort of proto-Demeter. The lush exaggeration of feminine contours that characterizes them may be only the play of male eroticism or at most the nuptial counterpart of the animal figures and cave drawings, which are thought to have given magical aid in the capture of the object desired.

(In the New World the Pluvial food grinding folk may be a link to later high cultures. Possibly the metate of Mexican corn grinding is a lineal derivative from the grinding stones found in the oldest sites from Oklahoma to California. The age, content, and meaning of our old grinding cultures still await serious comparative study. Little is known in the Old World that is comparable to them.)

The existence of Mesolithic was not recognized until long after Paleolithic and Neolithic were established concepts. Gradually the so-called "hiatus" between Paleolithic and Neolithic has been partly filled, mostly in Europe and its borders, but the Mesolithic record is still meagre as compared to anterior and subsequent time. The scantiness of Mesolithic data, it may be suggested, is connected with the fact that Mesolithic culture falls wholly within the time of the deglaciation:

(1) Throughout Mesolithic the sea level was rising. Coastal lowlands which these folk inhabited are now beneath the sea; human record is recovered from them only by such rare chance as the dredging up of Maglemose artifacts from the Dogger Bank of the North Sea. The greater part of our knowledge of the European Mesolithic significantly comes from parts of northern Europe in which isostatic upwarp of the land outdistanced rise of sea level. With rising sea level was associated increased alluviation of river valleys and continued burial of lowland living sites. The situation is reversed from prior times, for which terrace sites are most revealing. The recognition of Mesolithic sites is in general difficult: They are buried out of sight in lowlands; they cannot normally occur on terraces, unless isostatic; they post-date most deposits of glacial origin; where occurring as upland sites they are likely to be overlooked because they are physiographically nondescript.

(2) The desiccation of the Pluvial areas and attendant loss of game and seed and root harvest greatly reduced occupation in the dry interiors and on the western side of continents in low intermediate and subtropical latitudes. Widely dispersed occupation was replaced by few settlements along the margins of permanent or seasonal water.

(3) Skill at stone flaking reached its highest development in Upper Paleolithic and gave rise to readily recognized forms. The arts of the Mesolithic people were directed otherwise; their stone work was less in amount, poorer in execution, and less diagnostic. The kill of big game became incidental; heavy projectiles, great knives, and daggers were used less; instead the Mesolithic people worked with perishable plant materials.

Mesolithic sites are chronologically well determined in north Europe where isostasy has provided a clock; elsewhere, as about the Mediterranean the absolute and even relative positions of the individual cultures are uncertain. The North European sites are late and in their inclement situations are obviously marginal and partial extensions of the main stream of Mesolithic cultural developments, with parts of the older northern (Magdalenian) culture adhering. There is likelihood that the European Mesolithic is adventive in the main and that the new ideas, and perhaps people, came from the South and Southeast. A general derivation out of the Near East is likely, and the ultimate hearth may have lain farther east. We have as yet hardly more than a record of a far colonial fringe, in which the environment was not favorable to the entry of the full cultural complex.

Notable innovations in Old World Mesolithic are: (1) Reduction in size of most stone artifacts, especially the so-called microliths; (2) general use of the bow and arrow, perhaps originating before this, but at this time becoming very widespread, and perhaps linked to the microliths; (3) varied fishing gear, including advanced development of the harpoon, introduction of fish hooks, sinkers, and floats; (4) use of boats; (5) a new axe, the tranchet, probably a wood working tool;

(6) appearance of grinding slabs in the Sebilian of the Near East, probably early; (7) deliberate fashioning of stone by grinding, as in the doughnuts or perforated "mace heads" (a term showing the preoccupation of archeologists with notions of warfare), and cylindrical celts with ground edge; (8) domesticated dog, found in Mesolithic sites from the Near East and the Crimea to Portugal and the Baltic; (9) late, the making of pottery.

AS TO A MESOLITHIC CULTURE COMPLEX

The Mesolithic is not yet seen clearly enough to be delineated as are the times before and after. It still has the qualities of an interval, later than certain great culture complexes in the prehistory of Man, and earlier than another great record. With continuing archeologic study, the interval is getting greater length assigned to it at the far end. Archeologic evidence does not yet warrant making the Mesolithic equal to the whole period of deglaciation. Nor do I wish to argue that a great change of environment must make a great change in culture. It requires, however, no forcing of imagination to see in this period the trial arrangements and finally the full prelude to the Neolithic. These developments took a very long time unless invention suddenly became very different in kind and pace than it had been. It might help our inspection of the Mesolithic past if we concede the possibility that it may have involved most or all of the time of the deglaciation. This consciousness of need of a good deal of time, it may be admitted, is based mainly on the changes in plants and animals effected at the hand of man by the time when the Neolithic record begins.[19]

The meagreness of the Mesolithic record may be a permanently characteristic feature. The peculiar turn of events in earth history noted may well conceal from us forever more of man's history than for contiguous periods. We know from the subsequent period that a great deal must have been accomplished by man during the Mesolithic and it is not inappropriate to make the most of the clues we have.

Upper Paleolithic traditions of hunting life penetrate to some extent into the Mesolithic cultures, as in Magdalenian influence on Azilio-Tardenoisian, but the roots of Mesolithic culture are rather to be sought further back in the Paleolithic core or hand axe cultures, known in the western Old World as Acheulean and Micoquian. These are usually interpreted as fashioned by woodland folk, who favored humid and mild climates. They may have originated in Monsoon Asia. They directed themselves strongly to the exploitation of plant resources as to food, fiber, bark, and wood. A good deal of practical plant lore may be ascribed to them and a trend toward as much sedentary living as skill and environment permitted.[20] In Europe the older woodland folk were pretty much overwhelmed by the Upper Paleolithic hunting folk, but in lower latitudes their descendants were not thus disturbed.

Accepting the peripheral nature of the European Mesolithic, which is most of the record that we have and the connection with earlier hand axe cultures out of mild climates, the known dominant traits, namely, microliths, bow and arrow, fishing gear, boats, adze and axe, grinding slabs, pottery, and domesticated dog are sufficient parts of a mosaic to venture a preliminary hypothesis as to the nature of Mesolithic culture, its general place of origin, and its age. These particular traits are not discrete, but complementary; they do make sense together and in context with the newly formed environment.

It may be that, when we have more varied knowledge of Upper Paleolithic time than the European record affords with its dominance by hunters of plain and cave, the roots of Mesolithic origins will appear more clearly to come from a farther antiquity:

(1) The domesticated dog is almost the index fossil to Mesolithic sites, yet it may have originated before then. The Australian dingo may be part of a Paleolithic culture that has survived in isolation; certainly the animal was carried there by man. The doubtful reports of dogs in late Pleistocene deposits may be resolved by new finds or restudy. It appears reasonably sure to me that the dog does not belong originally to mobile hunting folk, and probable that its domestication was not a casual event, but a difficult step carried out only once. I think it was possible only to quite sedentary people.

(2) Those who venture to reconstruct the historical branching of cultural complexes from living peoples—and the effort is worth the risks—assign the *balsa* or raft boat to a culture of mid-Paleolithic aspect. The bark canoe is a later invention, but perhaps still Paleolithic, if the Aus-

[19] Ames, Oakes, *Economic annuals and human cultures*, Bot. Mus. Harvard Univ., 1939, especially the conclusion.

[20] Sauer, C. O., Early relations of man to plants, *Geog. Rev.* **37** (1): 1–25, 1947.

tralian culture complex is properly interpreted as a late Paleolithic relic.

(3) The trait of fish poisoning may be of similarly high age, being found in many parts of the world among tribes of simplest and most archaic culture. It again is widely present in Australia, was practised by the more primitive tribes of California rather than by the more advanced, and was the only means of taking fish known to the Ssabela of the upper Amazon, a people of extraordinarily archaic character.[21] The techniques of fish poisoning are in need of study as to their culture historical significance. The discovery may have been the result of processing fiber. A general procedure is the macerating of some part of a plant, usually root or stalk, and scattering the mash into the fishing pool. To a considerable degree the plants thus used are also used for fiber, and a number of them serve for toughening cords and nets (for Southeast Asia, for instance, species of *Derris, Albizzia, Diospyros, Daphne,* and *Barringtonia*).[22] Such may have been the original uses, and by preparing a certain fiber the observation was made that fish were made unconscious. Trial showed that these fish were safe for human consumption; then the trait of fish poisoning became adopted and the learning was passed on to others. These are some of the traces of possibly more ancient roots of the Mesolithic advance.

HYPOTHESIS OF THE PROGRESSIVE FISHING PEOPLE

The archeologic content and sites of the Mesolithic show attraction to the water side which is in contrast to the prior period. Attention shifts from land hunting to fishing and other riparian and aquatic economy. The water's edge sustained human groups as far back as we can trace man, but they had been quite conservative collectors, and are pretty well lost sight of during the Last Glaciation. With deglaciation and its attendant drowning of coasts and flooding of valleys a new environment was resolved into new opportunities by a series of cultural inventions, improvements, and recombinations. The cultural revolution of the Mesolithic was pioneered, by this view, by progressive fishing people who also initiated the basic steps in plant and animal domestication.

The harpoon was much improved and diversified during this period and the fish hook added, and so we know also that strong water resistant cordage must have been made. Netting also has been recovered on the Baltic, also bark floats and stone sinkers. Boat making was carried on. The simple bow and arrow, widely diffused during this period, is a precision weapon at short range, well suited for still hunting of water fowl and small water mammals as well as for shooting fish in shallow pools. It was not of much account for big game or for combat. The older "hand-axe" during this time was developed into wedge, adze, and axe, the latter toward the end acquiring a ground edge. Weight, shape, and size of these instruments indicate use for digging and hewing rather than for combat. The so-called stone maces or doughnuts may have been slipped over digging sticks, as was done in historic times in Central Chile. They would therefore be anticipations of the spade. In line with our martial traditions there has been inclination to interpret many things as fighting weapons; the cultural additions of this time were more apt for peaceful arts.

The habitat in which the new culture had its origin is thought of as having been at the edge of bay, lake, and stream, and the elaboration of the culture as progressive domination not only of the water side but the adjacent land side. Land plants were as important as water life; cultural progress depended on the increasing domination over both kinds of resources. Seaside habitat was less favorable to cultural development than was fresh water. The most backward culture of European mesolithic was that of the Asturian strandloopers, as Gordon Childe calls them. Some of the Brazilian sambaquís should also belong to this period. We still have in various parts of the world primitive peoples who are beachcombers, living on coasts rich in shellfish and perhaps fish, and almost mid-Paleolithic in their culture configuration. The open coasts offer a modest competence but seem always to have discouraged primitive ingenuity. Moreover, nonalluvial, coastal lands are below average in diversity of economic plants, and few from such areas have been made into domesticated plants. On the other hand, fresh water and alluvial soils do give the requisite background for the cultural advances that were realized by the beginning of Neolithic time.

The most probable hearth of the great Mesolithic developments is to be sought in Monsoon

[21] Tessmann, Günther, *Die Indianer nordost Perus,* 300, Hamburg, Friederichsen, de Gruyter, 1930.

[22] Burkill, I. H., *Dictionary of the economic products of the Malay Peninsula,* 2 v., London, Crown Agents for the Colonies, 1935.

Asia, somewhere from India to southern China. The preference for a Southeast Asiatic center of cultural origins is based on (1) its earlier role as cradle of human races and cultures; (2) the habitat requirements that have been postulated are well met by various parts of India, Indo-China, and southern China; (3) interior mountain barriers gave protection against raiding nomad hunters; (4) the position of the area is most favorable for culture dispersals involving water preferences; (5) a great number and diversity of old domesticated plants and perhaps the oldest domesticated animals derive from here. If domestication of dog and pig can be assigned to Southeastern Asia, the case becomes very strong.

The most nearly comparable area as to early advantages are the lands about the Caribbean and Gulf of Mexico, but the time involved seems too early to initiate a great culture center in the New World. Southwestern Asia is ruled out for consideration as a hearth in the critical period of beginnings, largely because I do not see that the things it contributed, such as small grains and other economic annuals and the larger domesticated animals, belong to the earlier stages of the sequence that led to agriculture. Since contemporary climates were already in force, its dryness is incompatible with the present hypothesis of the basic culture complex.

In Southeastern Asia both more primitive hill peoples and higher cultures share in institutions that may be derivative from the ancient fishing culture complex. From this area traits of social organization and ritual have been cited by numerous adherents of cultural diffusion as showing an early cultural nexus that became widely spread over the world, on the economic side some special aptitude in fishing, boating, and planting being recognized.

Southeastern Asia has a combination of plant-using traits that link fishing and farming and which seem to have originated in common and ancient procedure that may antedate even Mesolithic time, namely the crushing or macerating of plant parts and their washing. The beginning may well have been in the breaking and retting of fibers for bowstrings and net cords, with the discovery of fish poisons incidental thereto, as stated earlier. This is also the major center for making bark cloth, and for dart poisons, for both of which the processes have much in common with fiber and fish poison preparation. In no other part of the world is there such familiarity and variety in the use of poisons, chiefly from stem or root of plants, and numerous of these are important for fiber. The fearsome upas tree (*Antiaris toxicaria*), most potent component of dart poisons, has also been one of the main sources of bark cloth. The genus of breadfruits (*Artocarpus*) is "invaluable to the jungle tribes for the manufacture of bark cloth";[23] it also suplies fibers for fishnets and lines, and some species enter into the making of dart poison. Species of *Gnetum* furnish food from their seeds, strong and pliable fiber, and fish and dart poisons.

Various aroids are acrid or actively poisonous as to tuber or stem but have become important sources of starch food. They require rasping or grinding, with repeated washing before cooking. The *Alocasias*, especially *A. macrorrhiza*, are and formerly were more used and cultivated for their starchy stems. The *Colocasias*, or taros, in the wild and less ameliorated forms, are highly irritant, unless grated and washed before cooking, and this quality may have been originally responsible for the preparation of taro as poi paste. The tuber-bearing poisonous aroids that have yielded cultivated races of importance are *Amorphophallus campanulatus* and *A. konjac*. The treatment of yams (*Dioscorea*) was probably the same, and one kind still much used to the present (*D. hispida*) is very poisonous. Two of the cultivated gingers (*Zingiber cassumunar* and *Z. zerumet*) are on record as arrow poisons.

The more humid part of Monsoon Asia is the home of various non-poisonous esculent tubers important in the history of man, and often ground to meal before cooking. Some of them are aquatic or grow at the water's edge, such as the water "taro" (*Ottelia arismoides*), the arrowhead (*Sagittaria sagittata*), sweet flag (*Acorus calamus*), the tuber-forming sedges (*Cyperus esculentus-tuberosus-rotundus* complex), and water lilies (*Nelumbium nelumbo* and perhaps *Nymphaea lotus*). All of these are or have been cultivated, the rest of the world offering few hydrophytes that have been brought under cultivation as food-stuffs.

Finally, we have the securing of starch food from stems through shredding or pounding and thereafter separating the starch by washing. This making of sago is mostly limited to Monsoon Asia and is a trait of high antiquity. Certain cycads and palms are thus exploited, either in the wild,

[23] Burkill, *Dictionary*, from which the botanical data in this part are taken.

or brought into the village planting, namely *Cycas circinalis* and *revoluta, Arenga pinnata, Phoenix farinifera* and *rupicola, Coelococcus* ssp., and *Metroxylon laeve, rumphii,* and *sagu.* The fermentation of toddy from these and other sugary palm trunks is probably an associated trait.

The practice of shredding, pounding, washing, and decanting runs through plant uses throughout Southeastern Asia and seems to tie fiber making and toughening, poison preparation for fishing, hunting, and medicine, and food preparation, including the coagulation of sago, into one culture complex. The origin of this interrelated set of skills was favored by the presence of suitable plants, but it would appear to be derivative from the direction that intellectual curiosity took among a particular group of fresh-water fishermen.

PERMANENCE OF HOUSES AND VILLAGES

The process of domestication will not be explored further in this paper. I hold it to have been carried out, whether uniquely as to origin or not, by the culture which has been sketched, and mainly to have taken place during the period of deglaciation. The progressive fresh-water fisher folk, it is suggested, became in course of time the Earliest Planters (*Altpflanzer* of the *Kulturkreis* systems).

The life of such people was fully sedentary; they had no necessity to move about, for a good fishing site was such throughout the year. The water harvest was continuous, though the product might change with the season. The land also yielded its fruits proper to their season. Neither on water nor on land was there the sort of seasonal disparity that enforces migrant food searching. Houses were permanent and they were framed with wood or cane, and covered with cane or bark, by people who were also boat builders, men using adze and axe familiarly and who were applying their thinking to the fashioning of wood and cane. The "culture area" proponents are probably right in assigning the origin of the rectangular, framed, and gabled house to such a culture, and in emphasizing the spaciousness of such houses, which were combined living quarters, storehouse, and tool shed. Boat transport made easy the carriage of supplies from a distance and their assembly at a permanent base. Living was made better and more comfortable by the accumulation of goods. Since there was no moving day ahead, there was no restraint on the getting and keeping of goods. Personal property could be added indefinitely as long as it added to the comforts of home.

With the ability to range easily by water, it became advantageous to live together in villages, as at river junction or rapids, at lake end or narrows. The community had opportunity for diversified skills and for exchange of ideas. Association meant diffusion of ideas or learning; an innovation could become a group practice. By boat other settlements could be visited and ideas spread readily as far as there was intercommunication. Given leisure to experiment and to learn in an advantageous environment, such communities needed only sustained curiosity in a given direction to make the advance from fishing to farming. Since their interests were directed strongly toward plant processing, as has been outlined, increase in population and in experience made the understanding and use of the plant resources more and more rewarding.

Planters, I think, must be fully sedentary folk, and I cannot accept the widespread view that wandering people might plant a crop, wander on, and later return for its harvest. In the first place, I do not think that a definite season of crop harvest enters into the early steps towards agriculture, but that attention was first given to having certain plant items, not necessarily food-stuffs, conveniently at hand at all times. Our conventional views of proto-agriculture are still based on our own past as grain farmers of sown fields, which was not the way by which man took the first steps towards farming by such evidence as we have. Also, it is well known that primitive folk as we know them do not and dare not leave their plantings unwatched. The planted crop, in fact, must be watched over incessantly lest the creatures that fly, walk, crawl, and burrow move against the plantation to begin its destruction almost from the day it is made. There is partial protection by growing plants that are poisonous, but man's poison may be an animal's food. The predilection for dealing with poisonous plants as sources of food may, however, not be unrelated to their unpalatibility to plant predators. Only plants quite unpalatable to all the local fauna, however, have much chance of survival if left untended. The men folk may get away for fishing and hunting trips, but the women and children must stay to guard the plantings. This watching over the clearings against the wild life is indeed one of the first impressions that a civilized visitor gets from seeing a primitive agricultural or horticultural

community unless it be in far oceanic islands. The increased food supply for man is equally an increased attraction to a diversity of animals that compete for food with man, as every farmer knows. The myth of casual, untended sowing is part of the myth of the hungry mobile hunter who decides to add to his food by sowing seeds and capturing a herd of wild animals for their increase.

CONCLUSION

The general premise of this reconstruction is that there is no general succession of cultural stages. Nor was there general evolutionary transition of fisher folk to farmers. However, only in sedentary fresh-water fishing communities do I find the seminal qualities out of which came the Neolithic modes of life. The transformation of culture perhaps was pioneered only in one area, which most probably lay in Southeastern Asia. The change in mode of living by developing interrelated skills was one of the greatest in the history of man and required uninterrupted and long continued intellectual activity in one direction. Cultural diffusion is favored, therefore, as against independent parallel invention. Neither the invitation of a favorable nor the lash of a harsh environment in itself brings cultural advance. Time by itself works no social evolution of large proportion. There are certain parallels between biologic evolution and culture growth: High isolation stops progress early; too great accessibility leaves an area open to be swept by every invading force and without the chance to develop variant and novel forms. The hearths of human learning needed to be somewhat sheltered from the world at large but also to have the option of outside communication. They also needed ample and varied resources in their environment, so that thoughtful people could work with them, with leisure to experiment and reflect. The milestones of human learning have been set here and there at opportune times by a few exceptional groups in exceptional locations for discovery and transmission of ideas.

The time of the great deglaciation lies on the steeply ascending part of the curve of cultural innovation. We know now that our own kind, probably with our own intelligence, was in existence as far back as mid-Pleistocene, and that very slow increments of learning had been added here and there over hundreds of thousands of years. The last glaciation or Upper Paleolithic saw a notable acceleration of learning. The rate of innovation increased quite rapidly during Mesolithic, the bright days of cultural youth for the most progressive branch of mankind. Where and how this progress was achieved is still veiled, but the clues point to a great intermediary culture between older collectors and later farmers, of fairly low latitude habitat in wooded stream sides.

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